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For my children,
Wilf & Rex

Cybernetics in Music:
a philosophical and practical investigation

Abstract:

This thesis examines the use of cybernetics (the science of systems) in music, through the tracing of an obscured history. The author postulates that cybernetic music may be thought of as genera of music in its own right, whose practitioners share a common ontology and set of working practices that distinctly differ from traditional approaches to composing electronic music. Ultimately, this critical examination of cybernetics in music provides the framework for a series of original compositions and the foundation of the further study of cybernetic music.

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Chapter 1

Introduction

1. Cybernetics in Music – Thesis Introduction

The physical functioning of the living individual and the operation of some of the newer communication machines are precisely parallel in their analogous attempts to control entropy through feedback (Wiener, 1950).

This thesis is an examination of cybernetic theories and their application to musical composition. The primary concern of this study is to define a certain type of electronic music in a new way, with the aim of uncovering a common ontology that underpins the work of a number of eminent composers of electronic music, while tracing the development of a genre of music that has hitherto been obscured by other dominant trends. In the process, a framework will be generated in which cybernetic music may be viewed. This framework will then be utilised to interrogate these research findings within original musical compositions.

The first question that may justifiably be asked is: What is cybernetics? It is true that the words cyberspace, cyborgs and cyber-men and any other word that shares the cyber-prefix have their cultural root in cybernetics. Thus, it may be rightly assumed that cybernetics is synonymous with computers, machines, and robotics. However, the mathematics of cybernetics and its philosophical underpinnings have little direct connection with these tropes.

Cybernetics is the study of systems, or more precisely, the study of organisation in complex systems. The term cybernetics comes from the Greek word *kybernetes*, meaning the art of steersmanship when piloting a boat, and has the same root as the word for 'government' (Wiener, 1948). First used as a term by Plato, and later by Ampère in the nineteenth century, cybernetics was conceived in its inception as the science of effective government.

Modern cybernetics was defined by the mathematician Norbert Wiener in his formative publication *Cybernetics, or Communication and Control in the Animal and the Machine* (Wiener, 1948). Wiener's cybernetics pertains to the study of systems, their structure, regulation, constraints, and possibilities. His thesis outlines a number of related mathematical theorems that pertain to time, statistics, information, feedback, the nervous system, the perceptual senses, the brain, language, and society. His cybernetic vision came from the interdisciplinary nature of the government military projects on which he worked during the Second World War. The field of cybernetics as we understand it today was born in this milieu and coalesced at the Macy conferences – a series of meetings among a group of interdisciplinary scientists and medical doctors that took place in New York between 1941 and 1960. In the late 1960s and 1970s, cybernetics began to broaden its appeal as its theories and ideas became incorporated into the social sciences and eventually found an expression in art, music, and popular culture.

Cybernetics is peculiar among modern sciences because of its major influence and yet relative obscurity in modern academia. Since its inception, cybernetics has played a major role in the development of many scientific fields, such as artificial intelligence, complexity science, information theory, chaos theory, control theory, general systems theory, and robotics. However, due to its interdisciplinary nature (there are currently many more sociologists, biologists and architects practicing cybernetics than computer scientists), cybernetics as an overarching and autonomous discipline has struggled to become established. One fundamental reason for this is that research departments and academic programmes have not hitherto been in the habit of catering to holistic disciplines. Furthermore, the spin-off fields mentioned above have been far more effective in gaining funding, often due to their military and defence applications. Artificial intelligence, in particular, gained almost all of its academic funding in the United States from the DARPR, an agency of the US Department of Defence (Chapman, 1995).

While the early preoccupations with command and control in cybernetics infer seemingly sinister implications, after his experiences working in defence research for the United States government, Wiener himself sought to present cybernetics as a non-militaristic science. He outlines this cybernetic liberal-humanist agenda in his book, *The Human Use of Human Beings* (1950), which prefigures the sociological turn that cybernetic study took during the early 1970s. On the implications of the compartmentalised use of science during the Second World War, Wiener asserted: "The measures taken during the war by our military agencies, in restricting the free intercourse among scientists on related projects or even on the same project have gone so far that it is clear that if continued in time of peace, this policy will lead to the total irresponsibility of the scientist, and, ultimately, to the death of science. [...] The interchange of ideas, which is one of the greatest traditions of science, must of course receive certain limitations when the scientist becomes an arbiter of life and death. [...] I do not expect to publish any future work of mine which may do damage in the hands of irresponsible militarists." (Wiener, 1947)

Cybernetics is at its root a science of analogy and metaphor (Hayles, 1999), of which the most pertinent is that machines are like living organisms. This analogy can be demonstrated from an information perspective; analogical relationships can be constructed between living and mechanical systems that demonstrate similar patterns of information and behaviour. It is important to note that in cybernetics, "analogy is not merely an ornament of language but a powerful conceptual mode that constitutes meaning through relation" (Hayles, 1999). It allows us to cross boundaries, for the opposite of drawing an analogy is to construct a boundary. Analogy offers a different line of enquiry and a powerful conceptual framework in design.

Cybernetics also concerns the study of self-sustaining entities. Louis Kauffman, President of the American Society for Cybernetics, gives this definition: "Cybernetics is the study of systems and processes that interact with themselves and produce themselves from themselves" (Kauffman, 2007). An important facet of this line of enquiry is that cybernetics, in the main, is not concerned with linear cause-and-effect processes. Instead it seeks to examine emergent properties that a system may exhibit and recognises the probabilistic processes and circular causality that may act upon, and are at play within, a system. To the cybernetician, the world is not a set of truths or epistemologies that lay concealed waiting to be uncovered, but instead presents a continuing "dance of agency" (Pickering, 2011) in which discovery is only meaningful in a performative context. Cybernetics holds the view that learning, intelligence, and creativity take place in an embodied setting; they are formed when agents interact with their environment. They are not constructed in the mind alone, but happen via an interactive feedback process, which is a very different conception from the traditional Cartesian view. This particular meta-systemic focus allows us to ponder how entities, living or otherwise, contravene entropy to create structures that are self-sustaining and have meaningful emergent properties.[1] This constructivist approach underpins this thesis and helps to address the creation of self-sustaining musical works that have emergent musical properties.

Cybernetics is also unusual because of the peculiar ontology its investigation evokes, which runs counter to much modern thinking. The philosopher Bruno Latour (1993) argues that modern thinking is dualistic, in that it separates people from things. He observes that this dualism is institutionalised in our schools and universities, which split the natural sciences (from which people are distinctly absent) and the social sciences (the human realm), and thus a dualist ontology presides. Conversely, because cybernetics is concerned with systems, it is much less interested with what things are (the epistemology) than what they do. Animate and inanimate entities gain equal footing when considering flows of information and performative action in the world. One such example of this is cybernetician Gregory Bateson's thought experiment in which he ponders, "Is a blind man's cane part of him?" In addition, classic cybernetic research projects concerned with such things as synthetic brains and interactive machines "threaten the modern boundary between mind and matter, creating a breach in which engineering, say, can spill over into psychology, and vice versa. Cybernetics thus stages for us a non-modern ontology in which people and things are not so different after all" (Pickering, 2010).

Cybernetics not only stands as a challenge to modernity and modern thinking in science. In its application to other subject areas and in particular relevance to this thesis, its application to music, it stands as a challenge to many modernist ways of thinking about composition. For example, rather than music being formulated in the mind of individual composers to be disseminated hierarchically into the world, cybernetic music sees the compositional process and forming of meaning-making as being an interaction between composer, technology, audience, and environment, with each element playing an integral part. Cybernetic music is not fixed compositionally, either by the symbolic representation of notation, or by a platonic idea of a perfect musical form. Instead it is an ephemeral dance of agency, which may exhibit emergent properties that we may define as music.[2]

The organic, constructivist viewpoint that cybernetics offers provides a different perspective from which to examine and create music and organised sound with technology. It offers a design ethos that seeks to uncover underlying structures and modes of organisation that may assist in creating musical works that may be reflexive, interactive, or self-organising. It is particularly useful as an ethos that may be employed in the creation of works that do not seek to obey formal musical structure, especially those that utilise electronic technologies and require a meta-

[1] Thus we may see how philosophical questions of what constitutes life or consciousness arise in cybernetic discourse.

[2] This cybernetic critique of music and notation is similar to number musicological standpoints, espoused by figures such as Christopher Small, Lydia Goehr and Bruce Ellis Benson. However, the primary concern of this thesis is the relationship of music to cybernetics and the praxis that arises from this specific ontology.

language beyond formal notation that speaks to what is common between human, machine, and environment.

According to Heinz von Foerster, circularity is the central theme of cybernetics (von Foerster, 1980); autonomous systems are always embedded in environments and subject to feedback processes. The feedback loop, the flow of information from entity to environment and back again, is at the core of all cybernetic processes. Organisms (and machines) may choose to reinforce or suppress environmental stimuli based on this constant flow of feedback information. It allows for entities to make internal or external changes and to adapt to environmental conditions. Feedback allows for self-sustaining organisms that have agency within the world. According to the cybernetician Peter Cariani, "cybernetics concerns the organisation of effective action in the world via the incorporation of ends into means" (Cariani, 2010). This statement not only emphasises the performative ontology of cybernetics. It also recognises the circular causality of certain types of goal-orientated behaviour, where ends (goals) feed back into means. Such feedback mechanisms can be found in both technologies and evolutionary processes. This trope is examined in this thesis in its relation to how technologies are employed in cybernetic musical composition and how this differs from established approaches to using technology in musical composition.

The concept of feedback is integral to this thesis. It will take a central role, both in the uncovering of cybernetic tropes and cybernetic commonalities in composers' works, and as a conceptual and physical tool to be employed in the creation of new, original works. Feedback, in engineering terms, occurs when an output signal is fed back into an input signal. The computer engineer Derek J. Smith states: "Two types of feedback need to be identified, namely negative and positive. Negative feedback is where corrective action is taken to reduce, or 'damp', the amount of an error. This is the sort of feedback, which gives us the classic 'closed loop' control system (e.g. a thermostat). It also gives us the feedback we are already familiar with in biology under the name homeostasis (Cannon, 1927). By contrast, positive feedback [for example, audio feedback] is where the correction is made in the same direction as that of the original displacement. Each pass around the feedback cycle thus magnifies the displacement instead of diminishing it" (Smith, 1997). Feedback creates a rapid escape from the initial signal or form and results in exponential outputs or complex structures. In the work of many cybernetic composers, the nature of this complex regeneration is often formed from sound in the environment, which can be adapted using DSP processes to evolve in exponential or unpredictable ways. In tandem with this generative process, DSP is also used to dampen and control the nature of the exponential outputs, thus a state of equilibrium between these two processes is sought. This conception of cybernetic music reflects the human/machine/environment paradigm, which is central to cybernetic theory and the use of feedback to control entropy, thus creating a homeostatic or autopoietic state.

The purview of this thesis pertains to cybernetics and electronic musical composition. However, it is important to state that this is not composition by traditional means; that is, notation is not the primary mode by which composition may be represented in this context. Therefore, it is perhaps more epistemologically pertinent and relevant that the subject area of music technology be the residence for these ideas and modes of approaching composition mediated by technology. Music technology is a relatively new, multi-disciplinary academic field, and as such is still searching for overarching theories that encompass technology and music, which stand apart from most of the writing on the subject of modern composition that stems in the main from formal writings about music. This thesis aims to provide a specific academic context by which music composition that does not require notation may be justified as part of a music-technology epistemology. This therefore implies that this thesis contains critiques of scientific theory, philosophy, philosophy of science, technological design, and aesthetics, as well as musicology and music.

The infusion of cybernetics into the music-technology and compositional canons is highly relevant to the questions that recent technological advancements pose, as Heylighen and Joslyn postulate: "As reflected by the ubiquitous prefix 'Cyber', the broad cybernetic philosophy that systems are defined by their abstract relations, functions and information flows, rather than by their concrete material components, is starting to pervade popular culture, albeit in a shallow manner, driven more by fashion than by deep understanding. This has been motivated primarily by the explosive growth of information-based technologies including automation, computers, the Internet, virtual reality, software agents, and robots. It seems likely that as the applications of these technologies become increasingly complex, far reaching, and abstract, the need will again be felt for an encompassing conceptual framework, such as cybernetics, that can help users and designers alike to understand the meaning of these developments" (Heylighen and Joslyn, 2001). As technology becomes ever more ubiquitous and personalised, the human/machine/environment framework that cybernetics offers becomes ever more pertinent, and a musical form that reflects this metamodern state seems ever more relevant.

Whilst there are many compositions and examples of the musical implementation of feedback, there is no research that examines feedback or cybernetics in the terms proposed in this thesis, as the basis for a new interpretive framework and generative compositional mode. For example, at present there are very few specific titles (and almost none outside the writings of some of the composers considered in this thesis) that refer to cybernetics in the RILM Bibliography. There is currently only one paper (Dunbar-Hester, 2010) that seeks to catalogue a collection of cybernetic composers and by the author's own admission, the diversity of cybernetic music practice presented "a major difficulty in addressing cybernetics as a homogeneous or monolithic discourse" (Dunbar-Hester, 2010). Put simply, the purview of this thesis has not been examined hitherto. This study therefore aims to address the deficit of research in this area, and through hermeneutic, scientific, and musicological enquiry, seeks to present cybernetic music as a coherent genre of music that shares a common ontology and a common set of musical practices. This new analysis and the framework it generates will provide an original and important contribution to practitioners and the academy, which will enhance current understanding, not only in providing a new perspective on composers who have worked in this field, but also in new and original creative and technological outputs. This research also runs counter to many accepted methods of symbolic artificial intelligence employed in music informatics and many compositional systems that utilise computers, and as such, it proposes an original way of defining a certain type of electronic musical composition as *Cybernetic Music*.

The key aims of this study are to assess the significance of cybernetics and feedback in past and potential future musical applications; to provide a new interpretation and perspective on existing compositions; to generate useful criteria that will be applied in the creation of organised sound; and to interpret and apply research findings in musical compositions and performances that will interrogate the relationship between feedback, creativity, and technology.

The fundamental objectives of the thesis are as follows:

1. To evaluate the role that cybernetics and feedback have played within music composition.
2. To demonstrate that cybernetic music has a compositional ethos that fits within an established canon of musical works.
3. To interrogate these principles in original musical compositions.
4. To develop a vocabulary of performative music practice based on cybernetic principles.
5. To design technological and creative systems that aid cybernetic composition.
6. To critically evaluate the relevance of cybernetic music to composition and justify my own work within this paradigm.

Finally, as the philosopher of science Andrew Pickering points out, where cybernetics is concerned, "ontology makes a difference" (Pickering, 2011). Pickering reasons that the modern sciences are obsessed with epistemology and the assurance of ultimate explanations of reality. However, the ontology of unknowability that cybernetics presents is distinctly missing from the modern scientific worldview. This non-modern ontology comes to the fore when considering exceedingly complex systems, which may only be known by interacting with them. According to cybernetics, the human brain is the prime example in this instance. However, many other much more basic systems exhibit complexity that cannot be predicted by mathematical modelling or any other form of scientific representation. Pickering cites the work of theoretical biologist Stuart Kauffman and the computer scientist Stephen Wolfram (among others) as examples of the type of simple systems that exhibit exceedingly complex behaviours. Kauffman's work in computer simulations of complex systems in the 1960s demonstrated how simple structures could emerge that had their own dynamics, which could be interfered with, but could not be controlled. Wolfram's work with cellular automata demonstrated that under the simplest formal mathematical rules, the time evolution of cellular automata can very quickly become complex to the point of 'unknowability' – the only way to know what such a system will do is to run it and see what happens (Pickering, 2011). Pickering argues that this type of 'knowing' of complex systems is a staging of what he terms "ontological theatre". In fact, he postulates that cybernetic practice, and in particular the building of machines and systems in the cybernetic idiom, is peculiar among the modern sciences as it stages ontological theatre for us, a different way of imagining what the world is, and of explaining how it works. This thesis explores what it means to compose electronic music from this ontological standpoint, what this means when constructing a technological design ethos for composing, and what music that stages ontological theatre for us might look and sound like.

Chapter 2

Methodology

2. Methodology Chapter

Being is a process of becoming (Kierkegaard, 1864).

This section of the thesis examines the theoretical standpoint from which all musical works herein will be examined and the framework from which all musical compositions herein will be created and evaluated. The methodology described below stems from the core interest of this thesis, which concerns the composition of electronic music and the new frameworks and possibilities that cybernetic music will allow in this creative process.

Before examining the areas of study for the thesis, it is important to state the ontological and epistemological framework under which the study will be conducted. The following section concerns some of the origins of cybernetic thinking and how they pertain to wider philosophical and musical ideas.

2.1. The Ontological and Epistemological Position

Cybernetics offers an ontological and epistemological position that differs from a number of conventional and well-established traditions (particularly formalism, causality, and artificial intelligence). In considering the purview of cybernetic enquiry, it is useful to examine the work of one of the founding fathers of cybernetics, Norbert Wiener. He began his academic career in the early part of the twentieth century as a mathematician studying Brownian motion. His insights in this field brought him to the conclusion that the universe operated in probabilistic terms. He hypothesised that initial conditions at the particle level could never predict the outcome of a situation, but could only give an indication as to a myriad number of outcomes. Moreover, he thought (as did Heisenberg) that initial conditions could never be precisely known. This idea is in direct opposition to Pierre-Simon LaPlace's assertion that given the knowledge of initial conditions and enough computing power, a system's evolution could be predicted for all eternity. That is to say, that the universe could be precisely knowable (Hayles, 1999).

It was from this probabilistic ontology of unknowability – sometimes referred to in relation to cybernetics as 'black box ontology' (Pickering, 2011) – that Wiener began to develop cybernetic ideas from the then nascent field of information theory. His theory equated the uncertainty of the quantum world to uncertainties within the world of communication. In commenting on Wiener's cybernetic vision, the postmodern literary critic N. Katherine Hayles postulates: "Statistical and quantum mechanics deal with uncertainty on the microscale; communication reflects and embodies it on the macroscale. Envisioning relations on the macroscale as acts of communication was thus tantamount to extending the reach of probability into the social world of agents and actors" (Hayles, 1999). From this perspective conventional ideas of cause and effect, of a deterministic universe, become less tangible. Instead, events and outcomes become blurred, leading to the notion of circular (not linear) causality. The cybernetic framework that Wiener proposed sought to demonstrate how messages and structure may arise from pure noise, and how life itself may be understood as patterns of organisation (Wiener, 1950).

Ontologically, the cybernetic position can also be said to be one of 'emergence'; structure *emerges* from chaos, living organisms exhibit *emergent* behaviour and order can *emerge* from the entropic void. Cybernetics de-emphasizes the beginning and end, or the cause and effect, and focuses instead on the state between: the emergent factors. Emergence in cybernetic terms pertains to structures or patterns that arise from the interaction of smaller, simpler discrete entireties, such as, for example, the patterns made by flocking birds, or individual ice crystals forming the complex and unique pattern of a snowflake. Emergence pertains to the behaviour of complex systems and offers a standpoint from which phenomena such as biology; being an emergent property of chemistry, or thinking; being an emergent property of the brain, may be understood (O' Connor and Wong, 2012). In cybernetic compositional terms, music becomes an emergent property of the interactions of smaller sonic elements. Composers such as Xenakis and Brün have made emergence central to their compositional ideas. In Xenakis' case, this is incorporated into his theories of the interaction of sonic grains forming emergent structures; in Brün's case, this takes the form of serial computer processing of audio elements producing emergent sonorities. Emergence is a vital concept in cybernetic composition and all the composers considered in this thesis engage with this notion in some form.

To recognise the emergent is to view the world from a constructivist standpoint, which recognises the integral role of environmental characteristics at play in any dynamic system; an entity is not separate from its environment; it emerges from it and is contained within a wider universal system. To use a musical analogy, in this new mode of electronic composition, musical works are no longer disseminated hierarchically; from composer to musician (and/or technology) to audience, but instead, compositions are a negotiation between the composer, the musicians (and/or technologies), and the audience. In the hierarchical formulation, environmental factors are seen to be irrelevant or superfluous to the transmission of information (Eno, 1976). In the cybernetic model, all elements of the system form a non-hierarchical balance of control. Environmental factors are recognised and form a part of the overall equilibrium. To recognise environmental characteristics in this way accords with a number of modern philosophers who assert the primacy of context and in particular communities in forming knowledge and shaping being. Gadamer, Kuhn, Foucault, Rorty and Fish all share this viewpoint (Coyne, 1995).

States of between, emergence, and transition are reflected in many philosophical and cultural texts that have a bearing on the ontological basis of this thesis, particularly how one might envisage a state of 'being', which is in a constantly emergent state. In thinking about being, Hegel states: "after pondering being in this pure way, we are led to realise that we are thinking of the possibility of there not being anything at all – or, more precisely, the thought of pure indeterminate being slides into the thought of nothing. Yet thinking of nothing is not ceasing to think". He further postulates: "A thought slides into its opposite and back again. In the case of being, to think of pure being is to think of it disappearing into its immediate opposite. To think of being is, therefore, to think of something else, the transition into nothing whatsoever, then back again into being. It seems, then, that thought is about something else apart from being and nothing. It is about transition" (Houlgate on Hegel in Coyne, 1995). Once again, the theme of entities emerging into being from the void is present and this relates to ways of thinking about compositional structures explored in this thesis, in particular, ex-nihilo (out of nothing) creative processes, or musical structures that emerge from noise or interactions of sonic grains, or some form of exponential generative process.

As previously stated in the introductory chapter, the purview of this thesis lies within the realm of music technology and therefore when considering a musical ontology, technology must also be considered in equal measure. Martin Heidegger has provided one of the most important critiques of being and technology in modern times. Although somewhat mystical in nature, Heidegger's philosophy clears a path to thinking about how technology may be employed in a meaningful way. Heidegger asserts that technology 'enframes' existence. It is entwined in the very fabric of being, and nothing can escape its thrall. This enframing is so absolute that it has led to a withdrawal of being; we are no longer able to see the mystery within things. Heidegger says that our response to this withdrawal should be a "letting be". We are not able to control the withdrawal but we are able to be aware of it and attempt to be "open to mystery within things" (Heidegger, 1954). In this way we are able to participate in the withdrawal in a more radical way. We are thus able to see the depths of the abyss and respond in a knowing way (Coyne, 1995).

In a 2002 text on *Postmodernism and the Postmodern Novel*, authors Keep, McLaughlin and Parmer state: "Where modernism thought of itself as a last-ditch attempt to shore up the ruins of Western culture, postmodernists often gleefully accept its demise and plunder its remains for artistic material." They also conclude by speculating that postmodern authors will "turn the detritus of our collapsing 'meta-narratives' into the stuff of a new mode of representation". Furthermore, this literary experiment will take place in what they term "the ethereal void of the electronic word". Here we see both recognition of the void (as referred to by Heidegger as the 'non-ground'), and the allusion to the act of ex-nihilo creation: an emergent creative experiment, enframed in a technological milieu. While this is by no means a complete encapsulation of postmodernist thought, these ideas are pertinent to this thesis as they point toward the technological and creative possibilities inherent in postmodernist tropes.

There are other ontological facets that should be considered here, namely where the thesis stands in relation to the two overarching movements of our era: modernism and postmodernism. Again, the theme of *between* arises: the argument of this thesis oscillates between the modern and the postmodern. It stands in opposition to some of the central tenants of modernist music, that is to say, the formal (musical) system, hierarchies of 'low' and 'high' art, and the need for a composer's individual style.[3] Conversely, it embodies modernist traits, such as an interest in abstraction and paradoxes, an interest in an internal 'I' (i.e. concerns with consciousness), and the creative use of systems.

Furthermore, it is postmodern in some important ways, such as, the atomization of the self (in authorship), the creation of meaning from '*différance*' (Derrida in Berger, 2003), a concern with self-referential structures, and the "incredulity to metanarratives" [formal systems] (Lyotard in Berger, 2003). It seeks to be egalitarian, drawing on ideas prevalent in classical, avant-garde, and popular music traditions

[3] See chapter 7 of this thesis, *The Cybernetic Compositional Framework*- P. 126, for a comprehensive analysis of where cybernetic music stands in opposition to modernist music.

(where there is little distinction between 'high' and 'low' art). It posits something new, particularly in compositional method, and also in what is 'asked' of the audience, as meaning is founded in negotiation.

So whilst the thesis encompasses tenets of both modernism and postmodernism, it only rejects some modernist ideas and in many respects occupies space both between and outside of both paradigms. As Andrew Pickering points out (Pickering, 2011), the ontology of cybernetics itself is distinctly non-modern, both in its rejection of modern academic dualism and in its emphasis on ontology over epistemology (also a preoccupation of Phenomenologists such as Heidegger, and Pragmatists such as Dewey (Coyne, 1995)). This boundary-crossing, non-hierarchical position is also aligned with the man-machine egalitarianism found in much post-human discourse, as ascribed by writers such as Wiener, Hayles, Gray,[4] and others.

The cybernetic composer Brian Eno describes two states of being that inform his work: "All of the encouragement of modern life is to tell you to 'pay attention to yourself' and 'take control of things'. We can invent technologies and we can think of ways of organizing the world to our advantage, to our benefit. However, the other thing we obviously love doing is almost completely the opposite; putting ourselves in positions where we're not the primary figure, where we are not in control, we're carried along, floating on something. I like this state, which I call 'surrender' and others call 'transcendence'" (Eno in BBC, "Arena", 2010). The practical content of this thesis will explore both these states, and their relevance to musical composition: to surrender to the automatic flux and flow of generatively created soundscapes, while simultaneously being able to focus on them and manipulate them for musically beneficially outcomes. This state of surrendering to the flux, while at the same time manipulating for advantageous outcomes is best summed up in cybernetic terms by Stafford Beer's prescriptive conceptualisation of how cybernetically designed systems work in practice: "instead of trying to specify it in full detail, you specify it only somewhat. You then ride on the dynamics of the system in the direction you want to go" (Beer, 1972). Beer's ideas were central in developing Eno's compositional systems that employed technology (Whittaker, 2003). Ideas also parallel Heidegger's response to the withdrawal of being: 'letting be' while simultaneously participating in the withdrawal in a more radical way. Here again the theme of 'between' is discovered.

Epistemologically, this thesis does not align itself with Hegel's 'positive' idealism, the continuing positive forward movement of knowledge, to which both modernism and postmodernism are related. Instead, it is aligned with Kant's 'negative' idealism. This position is defined in terms of 'as-if' thinking (Vermeulen and van den Akker, 2010). As Curtis Peters explains, according to Kant, "we may view human history as if mankind had a life narrative which describes its self movement toward its full rational/social potential […] to view history as if it were the story of mankind's development" (Peters in Vermeulen and van den Akker, 2010). They further define this position in relation to metamodernism, as "attempting in spite of inevitable failure", and "seeking a truth that it never expects to find" and go on to state that "humankind is not really going toward a natural but unknown goal, but they pretend to do, so that they progress morally as well as politically" (Peters in

[4] Specifically, Wiener, 1950; Hayles, 1999; and Gray, 2002.

Vermeulen and van den Akker, 2010). It is also worth stating that 'as-if' thinking is in accordance with 'black box ontology' and the notion of circular causality that lies at the heart of cybernetic discourse, where the emphasis is not on start and end points and a progression from one state to the next, but on the ultimate unknowability of outcomes and the sustainability of an emergent state. Ideas of the ultimate unknowability of reality in modern times date back to Pascal, who went against Aristotelian precepts and the ideas of Descartes to posit that there is no such thing as a priori knowledge, but that this should not prevent scientific investigation. In a sense, this is a performative ontology, one in which we may only know the world via interacting with it (BBC "In our Time", 2013).

This epistemological position also resonates with Nietzsche's 'perspectivism', a position that is "against positivism" (which he believes provides only facts). In describing the antidote to this, he states: "in so far as the word 'knowledge' has any meaning, the world is knowable; but it is interpretable otherwise, it has no meaning behind it but countless meanings – perspectivism" (Nietzsche, 1987). So the best way of knowing something is to attempt to see all perspectives and to accept that all perspectives, including one's own, are driven by "a lust to rule; each one has its perspective that it would like to compel all the other drives to accept as a norm" (Nietzsche, 1987).

Derrida goes further in uncovering the 'non-ground' that lies beneath the foundations of meaning (in language). No word can be said to have ultimate meaning; meanings are constantly shifting in a "play of signs". Analogies may be drawn from Derrida's work and applied to musical analysis. The underlying meaning of a musical work is not just culturally dependent; it is constantly "under erasure" (Derrida in Coyne, 1995). Again, from this standpoint, meaning within music can no longer be said to be disseminated hierarchically with no loss in transmission of intent, that is to say, compositions imbued with meaning by one individual, namely the composer, for exact interpretation of meaning by musicians and subsequently an audience. Instead, meaning is formed as a negotiation, between the composer, technology, and the audience. Herbert Brün's compositional theory of anticommunication, examined in this thesis, shares a strong relationship with Derrida's conception of the non-ground in the meaning of language. Brün's theory was developed from ideas present in communication theory, but it has a striking similarity to the implications of Derrida's ideas and presents a useful philosophical position from which to examine meaning-making in cybernetic composition[5].

The epistemological approach to the practical work that will be conducted as part of this thesis will be drawn from cybernetic analogies or metaphors – what the cybernetician Gordon Pask called "defensible metaphors" (Pask, 1966). The strength of using analogies in design is in the mapping of a viable model onto a nascent one. This is particularly apt in models of self-organising or reflexive systems and those that in some way seek to imitate the behaviour of intelligence or living organisms, which are conceptually difficult to model by other means. In all cybernetic models,

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[5] As previously mentioned (chapter 1, Page 3, footnote 2), philosophers and musicologists such as Christopher Small, Lydia Goehr and Bruce Ellis Benson have also espoused similar, long established, ideas in relation to meaning in music. However, the validity to meaning under examination here stems from Richard Coyne's Heideggerian and cybernetic critique of Information technology, which has been applied in this instance to offer a perspective on the relationship of cybernetic music to meaning.

feedback is the central self-regulating mechanism. Organisms can appear to have seemingly conscious behaviours and self-regulating and generating properties using feedback systems alone (Beer, 1972). There are a number of design metaphors that will be utilised in forming self-generating (musical) systems. One such model, employed by Stafford Beer in his book *The Brain of the Firm*, is the most viable living system known to us intuitively: the model of human physiology (Beer, 1972). Here, Beer maps the functions of the human body onto the functioning of a commercial enterprise. Beer's 'Viable System Model' will be further extrapolated in this thesis for use within a musical composition system.

Models of cognition and intelligence will also be appropriated, particularly those that are aligned with constructive theories of consciousness. Professor of cognitive science, Douglas Hofstadter, proposes a 'something from nothing' hypothesis of consciousness in his book, *I Am a Strange Loop* (Hofstadter, 2007), by asserting that the human brain is a mimetic system that mirrors the external world and is able to create ever-greater abstractions of the external world. Hofstadter postulates that at a certain level of abstraction the organism is able to observe its own actions within an environment and reflect on its place. This self-referential loop is what creates the illusion of an 'I' (Hofstadter, 2007). In looking to create artificial, self-generating systems, it is useful to consider self-referential depictive systems that are formed from the ability to create complex abstractions. Suffice to say that on a basic level, many art forms have this quality: all are in some ways mimetic systems, some are capable of abstraction, and some are also self-referential. This can be seen in forms of abstract art, film, theatre, dance, etc. In some instances music may also be viewed as an abstraction, for example of environmental sounds. The film sound designer and author David Sonnenschein notes that many of our emotional cues regarding sound and music are formed from our evolutionary capacity for psychoacoustic interpretation: the sounds of predators create fear; the sound of prey promotes action; rhythms promote sympathetic movements; the frequency range of human speech is heightened, etc. (Sonnenschein, 2001). Nonetheless, while music is a highly developed emotional language of abstraction and cultural convention, it is seldom self-referential and its abstractions are limited by such things as instrumentation (timbre, volume, pitch, playing environment, etc.).

However, in terms of music and sound in relation to Hofstadter's mimetic systems, the medium of recording provides an excellent metaphor; in recording the representation or mimesis of the external sound world is 'exact'. In addition, many further sophisticated abstractions can be performed (with DSP processing) and signals can easily be fed-back, thus enabling a self-referential perspective. The composer Agostino Di Scipio's work with sonic ecosystems exemplifies this paradigm. Di Scipio's self-organising musical systems are embedded in real spaces and utilise sound from these environments, which are manipulated via DSP processing and feed back into the environment in an evolving sonic process. Di Scipio's compositional model and his emphasis on composing interactions above the composition of sonic structures are explored in this thesis and extrapolated for use in original musical works. Arne Eigenfeldt proposes that "real-time composition ecosystems", such as Di Scipio's, should be considered as separate entities to electroacoustic compositions and improvisatory strategies: "They are a subclass of interactive systems, specifically a genre of interactive composition systems that share compositional control between composer and system. Designing the complexity of interactions between agents is a compositional act, and its outcomes are realized during performance" (Eigenfeldt, 2011). As this thesis will demonstrate, sonic ecosystems possess strong technological and theoretical links with cybernetic theory and in many ways may be viewed as the current culmination of the fusing of cybernetic ideas with musical composition. Eigenfeldt stresses that sonic ecosystems are different from traditional electroacoustic compositions and improvisatory strategies and thus should be considered as a different musical genre. This thesis explores the development of this distinct form of electronic composition and seeks, through original compositions, to reflect a number of important facets of its development and ethos, which differ from conventional norms in electroacoustic composition.

2.2. Defining Areas Of Study

There are a number of initial musicological starting points to the hypothesis, each of which highlights historical tendencies toward considerations of complex systems and self-organization in electronic music composition. As Christina Dunbar-Hester points out, in perhaps the only paper written attesting to something approaching a cybernetic music movement, "Listening to Cybernetics: Music, Machines, and Nervous Systems 1950–1980" (Dunbar-Hester, 2010), there is an oblique but longstanding tradition of applying cybernetics to music. However, while she does examine some of the main composers in this field (such as Louis and Bebe Barron, Herbert Brün, John Cage, Gordon Pask, and Brian Eno), other important contributors are not considered (Iannis Xenakis, Roland Kayn, and Agostino Di Scipio, for example). It is also fair to state that the paper explores few of the philosophical underpinnings and technological implementations of cybernetic music in practice.

In its musicological examination of cybernetic music, this thesis will focus on the work of composers who have explicitly cited cybernetics as a formative and longstanding influence on their compositional practice. However, one exception, Alvin Lucier, has been permitted for consideration, as his work and influence are so central to the infusion of cybernetic practice into composition that it was too compelling to ignore. Lucier has never overtly espoused cybernetic theory in either his written output or musical compositions. However, his musical theories and technological practice are steeped in the philosophical precepts of pragmatism – a school that is very closely aligned to the cybernetic ontology and thus allies directly with the purview of this thesis. There are other composers who it would seem are eminently eligible for consideration on similar criteria, in particular, Gordon Mumma (specifically for *Hornpipe* (1967)), and Steve Reich (specifically for *Pendulum Music* (1968)). However, these composers' works are only considered briefly, as in Mumma's case, cybernetics as a compositional ethos was only employed peripherally for a short period, and in the case of Reich, cybernetic ideas are not iterated at all and his use of technology and non-notational composition was very fleeting.[6]

[6] Please see Chapter 3 of this thesis: *Cybernetic Music in Context: a brief history of algorithmic composition and process music with electronics, and its relationship to cybernetic music*- P. 16, for further examination of these pieces

2.3. Research Areas

The structure of the thesis reflects the hermeneutic analysis of the composers' methodologies and the subsequent interrogation of these ideas and practices in a series of original compositions, which are analysed in cybernetic terms. Beyond the introduction, methodology, and conclusion, the thesis is divided into six primary sections, which illustrate differing practices and philosophical ideas in cybernetic composition.

- Chapter 3 outlines cybernetic music in context, providing a brief history of algorithmic composition and process music with electronics, and its relationship to cybernetic music. This chapter serves to elucidate on the milieu of the musical movements and aesthetics form which cybernetic music arose.

- Chapter 4 examines some of the pertinent philosophical and technological ideas that underpin cybernetic composition. This chapter serves to explicate in detail, facets of the argument of this thesis that are important to the understanding of composers approaches in subsequent chapters and the approach taken in the original compositions examined in Chapter 8. These facets include: the non-necessity of notation in this particular form of music composition and the pragmatic basis for this compositional approach; the cybernetic design ethos that is central to this technological compositional approach; and, in relation to this, the theoretical and mathematical phenomenon of feedback, which is examined in order to illustrate its practical and important role in the technological design of cybernetic compositional systems.

- Chapter 5 pertains to 'first-order' cybernetic music. It begins by further outlining the philosophical and technological basis underpinning cybernetic music, and proceeds through a number of founding cyberneticists and composers in the field, including Norbert Wiener's involvement in the development of the hearing glove, and the work of composers such as Louis and Bebe Barron, Herbert Brün, Alvin Lucier, and Roland Kayn. The term 'first order' pertains to a classification defined by many science historians and cyberneticians alike in order to distinguish between specific phases in the development of cybernetics as a body of scientific theory. 'First order' implies the founding period of the field, which was born from the interdisciplinary nature of defence research during World War Two and culminating in its official inception as a scientific field at the Macy cybernetics conferences in 1946, which were attended by a majority of the main cybernetic protagonists, including Norbert Wiener, Ross Ashby, Warren McCulloch, Claude Shannon, Gregory Bateson, and Margaret Mead. The founding of cybernetics displayed a preoccupation with control mechanisms, closed systems, homeostasis and analogies between animals and machines (Heylighen and Joslyn, 2001; Hayles, 1999). The composers studied in this section reflect, not only this time period, but also the philosophical and technological approach of first-order systems that tend to reflect the tropes of black box ontology, feedback, and closed systems.

- Chapter 6 is concerned with composers and cyberneticists that represent a distinctly 'second-order' cybernetic approach. Second-order cybernetics pertains to an evolution in cybernetic theory that occurred at the end of the 1960s. Wishing to distinguish themselves from earlier more mechanistic approaches, while encompassing the existing established cybernetic scientific precepts, contemporary cyberneticists defined second-order cybernetics by emphasising autonomy, self-organisation, autopoiesis, cognition, and the role of the observer in modelling a system (Heylighen and Joslyn, 2001). The composers chosen for inclusion in this section reflect this self-reflexive turn in cybernetic theory. Gordon Pask's musicolour machine and the work of the composers Brian Eno and Agostino Di Scipio exemplify and echo this evolved approach to cybernetic theory.

- The preceding research culminates in chapter 7, which presents the Cybernetic compositional framework, which defines cybernetic composition and informs the author's original work, which is examined in chapter 8. The preceding strands of study will be brought together here in order to assess the important musical applications and implementations of cybernetics in music, and to investigate where theoretical, aesthetic, semiotic, and musicological ideas of cybernetics have penetrated compositional practice. This will enable the exploration of the interrelationships of theory, practice, influence, and effect in a meaningful context and will prove useful in designing new implementations of technologies, which will be utilised in compositions that reflect the research.

- Chapter 8 encapsulates writings about three original compositions and performances that reflect this research in cybernetic music (the works themselves are included in the digital materials accompanying this thesis). These works stem from the author's experiments and implementations of feedback and cybernetic theory in musical compositions. These compositions utilise existing software from various commercial sources and also incorporate some bespoke software design. This section of the thesis is the culmination of the preceding research and, as such, provides an important element of the original contribution to the field. Further exposition and critical analysis of each of these works is also provided in order to exemplify the implementation of the cybernetic framework outlined in chapter 7.

Conclusions will be drawn in Chapter 9 from the original musicological and hermeneutic study to determine the parameters of cybernetic music and its distinctive nature in contrast to traditional approaches in electroacoustic composition. Further avenues of research in this area will be recommended and the implications of cybernetic music will be assessed in relation to current practice in electronic composition and possible future ramifications.

Chapter 3

Cybernetic Music in Context: a Brief History of Algorithmic Composition and Process Music with Electronics, and its Relationship to Cybernetic Music.

3. Cybernetic Music in Context: a Brief History of Algorithmic Composition and Process Music with Electronics, and its Relationship to Cybernetic Music.

"Since antiquity concepts of chance, disorder and disorganization were considered the opposite and negation of reason, order and organization. It is only recently that knowledge has been able to penetrate chance and has discovered how to separate its degrees" (Xenakis, 1971).

While the scope of this thesis on cybernetic music has already been stated and is strictly defined, it is worth taking some time to consider where cybernetic music might exist within the more general field of experimental and electronic music. To do this is to add context as to where the antecedents of cybernetic music lie and the areas where its influence may be felt. It is important to state that the following chapter does not provide a definitive history of experimental and electronic music, but its purpose is rather to cite a number of important touchstones that provide some context to this thesis. Cybernetic music may be seen as a type of generative music that favours heuristics rather than algorithms as its core procreant mechanism. Heuristics are a form of adaptable algorithm in which trial and error are key constituents in any formula. We may therefore see cybernetic music as being related to algorithmic composition and thus more broadly to experimental electronic music in which algorithmic composition forms a significant part.

3.1 The Origins of Algorithmic Composition

Cybernetic music can also be seen as existing within a tradition of music that incorporates chance elements in the compositional process. To the casual observer, this trend may appear to be a relatively contemporary idea springing from modernism and the algorithmic possibilities offered by computers. However, Curtis Roads states, "Composers have known for centuries that many musical processes can be formalized into symbolic representation" and that "behind modern efforts in algorithmic composition is a long tradition of viewing music procedurally" (Roads, 1996). He thus places algorithmic music in a historic tradition of experimentation in music. In addition, he also incorporates Process Music into his taxonomy of algorithmic composition. Roads dates the beginning of formal processes being used in music to 1026 and Guido d'Arezzo's development of a formal technique used for composing melody to text (Roads, 1996), however in truth this tradition probably dates back much further and sees its lineage emerge through instruments such as wind chimes, Aeolian harps, and the formalised improvisational techniques of the ancient world.

There are many examples in the Western art music tradition that exhibit generative qualities, including rounds, canons and fugues to name but a few. Perhaps the best-known example of formal generative methods being used in this mode is Mozart's *Musikalisches Würfelspiel* (Musical Dice Game), in which sequences of prewritten bars of music were assembled according to the throws of a set of dice (Roads, 1996). Victorian parlour games such as the Kaleidacousticon and the Quadrille Melodist used a deck of cards with instructions to randomise musical fragments into multitudes of compositional possibilities for pianists to perform in real time.

However, while such methods are interesting antecedents, it is with the advent of technologies capable of mechanically or digitally representing formal processes in music that composers become more fully engaged in algorithmic, aleatoric, or generative procedures in music composition. This is not to say that all composers engaged in these methods were using mechanical or digital means to produce their compositions. It is perhaps more prescient to consider that the idea of mechanisation and its implications, in all its varied forms, seeped into the artistic consciousness and permeated composers' methods. Cybernetics and cybernetic art and music can also be seen as part of this paradigm. This cross-pollination of technology and musical process in the modern era arises with the advent of modernism in the late nineteenth century. The academic Sara Danius proposes this exact thesis in relation to modernist literature in her book *The Senses of Modernism*: "the high-modernist aesthetic is inseparable from a technologically mediated crisis of the senses", and furthermore, "perceiving and knowing are realigned when technological devices are capable of reproducing sense data" (Danius, 2002). Within this framework we may see modernist music as existing in this technologically mediated milieu and its forms, to some extent, as reflecting a technological aesthetic.

3.2 Serialism

The 12-tone method created by Arnold Schoenberg (1874-1951) came to dominate the later modernist era in music between the 1920s and 1950s. While the development of the tone-row method can be seen as a direct progression from late romantic music, both aesthetically and in form, there is no doubt that the "formalised and systemic methods" of serialism (Roads, 1996) also chime with a technological/mathematical aesthetic. The musicologist John Borstlap defines the 12-tone method as "systems thinking" (Borstlap, 2017). This technical focus is echoed in Mary Simoni's statement that "algorithmic procedures lend themselves well to serial composition" (Simoni, 2003), and even Xenakis, a major opponent of serialism, concluded that: "the quantitative and geometric part of all music, becomes predominant with the Viennese School" (Xenakis in Kollias, 2011).

However, while the milieu of technological advancement and systems thinking had an influence on serialism it appears that this manifested itself in a relatively restrictive way. Schoenberg's student Anton Webern (1883-1945) and those that taught Schoenberg's methodology such as Olivier Messiaen (1908-1992) – and those who were taught by Messiaen, including Boulez and Stockhausen – progressed and enhanced serial methods, generalising the tone-row method to other musical parameters such as note durations and dynamic markings. However, despite these apparent advancements, Roads reflects that to some extent composers also became burdened with complex "precompositional" procedures. These adjuncts to the 12-tone method lead former serialist composer Herbert Brün (1918-2000) to remark that he eventually became "totally stuck" in an "absurd state of completeness" when attempting to compose in this way (Roads, 1996). Roads elaborates further in describing the perhaps inevitable backlash to such restrictive and prescribed methods: "in an attempt to break out of the extreme determinism of serial composition, European and American composers such as Karlheinz Stockhausen, Pierre Boulez, John Cage and Earl Brown experimented with aleatoric (and stochastic) methods of composition" (Roads, 1996)

3.3 Chance Music

This 'opposition' or move away from Serialism was undoubtedly spearheaded by John Cage (1912-1992). Cage, also a student of Schoenberg, is credited by many as one of the most influential composers of the twentieth century (Nyman, 1999). Cage popularised the use of indeterminacy in composition and significantly broadened what might be considered as music, with epoch-defining compositions such as *4'33"* (1952), *Imaginary Landscape no. 4* (1951), and *Williams Mix* (1952). Cage had a close relationship with technology, which can be seen as integral to works such as *Cartridge Music* (1960), *Fontana Mix* (1958), and *Williams Mix* (1952), but Cage was not alone in combining process techniques with technological means. Karlheinz Stockhausen (1928-2007) in particular was at the forefront of a European move to integrate technology into process-driven composition. His pioneering technological works of the 1950s, such as *Studie II* (1954), *Gesang der Jünglinge* (1955-56), and *Kontakte* (1958-60), are all fine examples of a technological imperative in his composition.

In the years following World War Two, Europe was particularly well served with electronic music studios, especially in comparison to America. Prominent examples were the RTF studios in Paris, the NWDR studios in Cologne, Germany and the RAI Studios in Milan, and significant European composers such as Berio, Messiaen and Stockhausen were thus able to access these technological advances with relative ease in comparison to their American counterparts (Holmes, 2002). However, many of these early works were still tinged with the pre-compositional burdens of the serialist method, Stockhausen's exhaustive scoring for his early tape work *Studie II* (1953) being such a case in point.

Cage's involvement with the electronic studios in America, in particular his work with cybernetic music pioneers Louis and Bebe Barron (which is examined in some detail in chapter 5.2 of this thesis), might be viewed as being more progressive than his European contemporaries. However, it should be noted that Cage's own compositional method, as employed in tape pieces such as *Williams Mix*, while not serialist in nature, was every bit as pre-compositionally encumbered as Stockhausen's techniques, with the need for a score of potentially reproducible results being a primary concern. It also must be said that these compositional methods were at complete odds with the unencumbered, non-score-based cybernetic processes employed in the Barrons' compositions, which utilised exactly the same equipment as employed by Cage. Nonetheless, Cage's stochastic methods, using the I Ching to determine musical parameters such as length of note and its envelope, were in sharp contrast to the controlled, deterministic, serialist methods employed by Stockhausen.

Needless to say, while twentieth-century musical titans such as Schaeffer, Messiaen, Boulez, Xenakis, Cage, and Stockhausen were engaged in electronic composition of one sort or another, it was only a few who were engaging in composition with aleatoric processes in the early 50s. Furthermore, only Cage employed these processes in electronic composition in this early, pioneering era of electronic music (Holmes, 2002).

3.4 Process Music and Cybernetic Music

In his book *Experimental Music, Cage and Beyond* (Nyman, 1999), Michael Nyman places Cage at the apex of experimental music. However, Nyman places enormous emphasis on experimental music *being* process music. To illustrate this point he quotes Morton Feldman: "In the music of both men (Boulez and Cage), what is heard is indistinguishable from its process. In fact, process itself might be called the zeitgeist of our age. The duality of precise means creating indeterminate emotions is now associated only with the past" (Feldman in Nyman, 1999). Nyman's seminal book covers process music as it emanated in the Fluxus movement in the 1960s to the birth of minimalism and beyond, and in many ways serves as historical context for the British minimalist movement in which he was to become a prominent figure with his compositional work of the 1980s. Nonetheless, Nyman's book is of particular interest to this thesis as it comprehensively documents the role of electronics in relation to the development of process music and it is at the intersection of process music and electronic music that cybernetic music finds its antecedents. Nyman's comprehensive examination of the electronic works of composers such as Alvin Lucier, discussed in detail in a later chapter in this thesis (chapter 5.3), is a prime exemplar of this cybernetic intersection. Indeed, in his technological analysis of Lucier's work, Thom Holmes cites him as being "the godfather of process music".

Nyman also examines the work of Terry Riley (b. 1935), whose early compositions also exist at this intersection of process music and electronics. Riley, a major inspiration in the development of Brian Eno's cybernetic music, is notable for being a pioneer in tape composition, process music, and a founder of Minimalism. Of interest to this thesis is the role his tape compositions played in preceding his influential minimalist pieces. In 1963 he produced a piece of tape music entitled *Music for the Gift* from recordings of Chet Baker's jazz ensemble. The piece was the first to use tape delay as a compositional mechanism (Holmes, 2012). In a method subsequently used to great effect in works such as Pauline Oliveros's *I of IV* (1966) and Brian Eno's *Discreet Music* (1975), a single loop of magnetic tape is fed through the record and playback heads of two widely-spaced tape recorders, so that the sound recorded on one machine is played back on the other, creating a tape delay, which is heard as long delays with successive, degrading repetitions (Holmes, 2012). Of this technique, Riley states that, "by varying the intensity of the feedback you could form the sound either into a single image without delay or increase the intensity until it became a dense chaotic kind of sound […] the engineer [on the recording of *The Gift*] was the first to create this technique that I know of. This began my obsession with time lag accumulation feed-back" (Riley, 1998).

This experimentation with tape loops and tape delay led Riley to a technologically influenced music of "repeating figures and pulse rhythms" (Holmes, 2012) and in the subsequent year he produced the seminal minimalist work *In C* (1964). *In C* consists of 53 individual short phrases related to the key of C, which are looped and played in loose order by an ensemble of musicians. A single piano note keeps a constant mechanical pulse while the non-contiguous looping phrases combine and interweave in a complex laminar soundscape. No two performances of the piece are the same, since the musicians make choices over which musical phrases to play in real time, as the piece is performed. Both these musical forms, the long tape delay and the generative qualities of *In C*, were hugely influential in the cybernetic compositions of Brian Eno and a combination of both mechanisms can be seen in Eno's tape-based works such as *Discreet Music* (1975) and "2/1" from *Music for Airports* (1978), and also in his work that utilises the KOAN generative music software, such as *Thursday Afternoon* (1985) and *Generative Music 1* (1996).

3.5 Iannis Xenakis and 'Free Stochastic Music'

The most prominent European composer to influence the development of cybernetic music was Iannis Xenakis (1922-2001). Xenakis' development as a composer was distinct and his work sharply contrasted with the serialism of his European contemporaries. While Xenakis began his career as a composer studying serial techniques with Messiaen in the 1950s, his previous training as an architect with Le Corbusier and a love of mathematics had a profound influence on the development of his work. Xenakis employed visual scores based on architectural concepts and mathematical procedures to produce a dense and complex orchestral music, whose key acoustic feature was "pointillistic noise" (Zografos, 2017). Xenakis' main conceptual break with serialism was the use of chance in his compositions. However, this was distinct from Cage's conception of chance operations, in which seemingly random processes, typically those determined by the I Ching, were used as a mechanism to determine musical parameters. Instead, Xenakis employed probability theory and mathematical formulae to create music that was "difficult if not impossible to compose manually" (Holmes, 2012). In his book, *Formalized Music: Thought and Mathematics in Composition* (Xenakis, 1971), Xenakis describes the mathematical inspiration for his pieces being the stochastic elements found in nature, such as the behaviour of crows, the sound of falling rain, or wind blowing through the trees. Xenakis states: "Since antiquity concepts of chance, disorder and disorganization were considered the opposite and negation of reason, order and organization. It is only recently that knowledge has been able to penetrate chance and has discovered how to separate its degrees – in other words to rationalise it progressively, without, however, succeeding in a definitive and total explanation of the problem of 'pure chance'" (Xenakis, 1971). Here again we see the influence of scientific and technological advances effecting musical process. Xenakis titled this mapping of statistical values onto musical parameters as "free stochastic music" (Xenakis, 1971). It is precisely this mapping of data onto musical values that has a distinctly cybernetic flavour and this theme in relation to Xenakis' work will be explored in some detail later in this thesis (chapter 6.3).

Xenakis was not the only European composer in the 1950s to engage in chance processes that were different to Cage's conception. Stockhausen and Morton Feldman, for example, wrote works such as *Klavierstück XI* (1956) and *Intersection No. 2* (1951) "where the performer is placed in a position to make spontaneous or rehearsed decisions about the ordering of the music" (Griffiths, 2001). Nonetheless, Xenakis' rigorous mathematical conception of incorporating stochastic means became his signature process. His first two works as a mature composer *Metastasis*

(1953-54) and *Pithoprakta* (1955-56) exemplify the foundations of his compositional approach and aesthetic. In the composition of *Metastasis*, Xenakis "drew an analogy between the movement of a gas molecule through space and that of a string instrument through its pitch range. To construct the seething movement of the piece, he governed the 'molecules' according to a coherent sequence of imaginary temperatures and pressures. The result is a music in which separate 'voices' cannot be determined, but the shape of the sound mass they generate is clear" (Choong, 1996). Le Corbusier's influence on the piece is also explicit in Xenakis' use of architectural graph paper to score the massed glissandi strings.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Fig. 1. String Glissandi, Bars 309-14 of Xenakis' "Metastaseis"(1953-54), Sourced from: http://www.furious.com/perfect/xenakis.html

However, Xenakis also utilised a 12-tone row in realising the composition, reflecting his debt to Messiaen. Xenakis' second breakthrough composition, *Pithoprakta*, reflected no such debt to serialism and is often regarded as Xenakis' first truly mature work, "in a style that acquires all its musical elements [solely] through mathematical theories and principles" (Zografos, 2017). Xenakis used probability theory as an inspiration for the piece; indeed the word *Pithoprakta* means "actions through probabilities". He used the statistical mechanics of Brownian motion to provide values that were mapped onto musical parameters. It is interesting to note that Norbert Wiener, the founding father of cybernetics, cites Brownian motion as one of his mathematical inspirations for cybernetics (Hayles, 1999). In *Pithoprakta,* Xenakis equated the individual movement of gas molecules in space to the pitch of individual string instruments. Again, he used graph paper to represent the mapping of time in the x-axis, and pitch in the y-axis. As Simon Emmerson notes, this compositional configuration still displays "the influence of the most traditional aspects of Western notation" (Emmerson, 2007). Nonetheless, as Emmerson describes it, these "models drawn from observations of the non-human world" (Emmerson, 2007) defined Xenakis' conception of a formalised music based on mathematical processes, which would form the basis for a compositional career of exploration in this area. This investigation led Xenakis to utilise cybernetic principles in a number of his works (see chapter 6.3 in thesis for further examination). It would also lead him to work extensively with computers on pieces such as *Amorsima-Morsima* (1962) and *Stratégie, Jeu pour deux orchestres* (1962), which assisted him in achieving his probabilistic compositions.

3.6 Chance in Computer Composition

There is no doubt that the advent in the late 1950s of computer systems capable of sequencing musical events greatly increased the possibilities of algorithmic composition. Composers such as Xenakis, who previously had to painstakingly assemble scores from equations and tables of figures, could delegate much of this preliminary work to a computer. Furthermore, with the correct software and programming, the computer could produce a score, whether visual or note-based, and in addition, it could also play back a synthesised representation of the score. However, the ability to create software that could improvise or generate its own original compositions was perhaps the most radical formulation of this new technological advance. Early forays into this type of compositional conception were undertaken with the Barr and Stroud Solidac composing computer at the University of Glasgow in 1959 and its "Dice-Music Master Program", and in Los Angeles in the early 1960s, Raymond Scott invented the Electronium, a large computer device that was programmed with knobs and switches that produced non-predictable outcomes. According to Scott "the Electronium is not played, it is guided" (Roads, 1996).

The work of Lejaren Hiller perhaps best exemplifies these early algorithmic compositions with computers. At the same time as Xenakis was writing *Metastasis*, Hiller and his collaborator Leonard Isaacson were producing the first computer-composed composition: the *Illiac Suite for String Quartet* (Roads, 1996). Programmed in binary code, The *Illiac Suite* was composed on the ILLIAC computer at the University of Chicago, where both men were professors. The score was assembled from four 'experiments'. The first three of these were attempts to 'teach' the computer different aspects of musical rules, melody, harmony, intervals, dynamics, etc., and to generate compositions based on these more traditional data sets. The fourth experiment was to use Markov chains, a stochastic mathematical process that randomises events in a sequence by allowing the computer to 'forget' all previous values in a data set except the figure that immediately precedes the next event. In musical terms this generates a sequence of notes that very rarely repeat. While Hiller pioneered these techniques, a number of prominent twentieth-century composers quickly followed, notable examples being Xenakis with *Atrées* (1962), Cage with *HPSCHD* (1969), Koenig with his *Project 1* software (1979), and Truax with *Arras* (1980).

Using chance in computer compositions continues to yield ever more complex formulations; the use of Cellular Automata in particular demonstrates a preoccupation with Artificial Intelligence and emergent behaviours that at first glance may seem to be related in some form to cybernetic composition. While these works are interesting in their own right and relevant to the milieu in which cybernetic composition was born and continues to grow, they cannot be considered truly cybernetic as the composition of cybernetic music consists of a human, machine and environment paradigm. The pieces explored thus far do not conform to this axis and in almost all cases the inclusion of the environment in the compositional process is almost entirely ignored.

3.7 Composition that Incorporates Human, Machine and Environment

The inclusion of the environment in composition is ubiquitous; every time a piece is performed live, in a concert hall, for example, the sound of the environment enters as a factor in the final sound world. However, the conception being considered here is one that is particularly pertinent to cybernetic music, namely the notion of the environment forming a conceptual and/or structural part of the composition, one in which environmental factors deliberately figure in providing the degree of the aleatoricism within a piece and, in turn, form a major part of the sonic outcome of the composition. This facet is considered multiple times in this thesis and forms a central tenet of what we might consider as cybernetic music. However, there are a number of composers whose work is not explicitly cybernetic, but who have nonetheless included the environment as a key factor in their compositions. A number of these antecedent compositions have also been influential on the subsequent work of cybernetic composers.

One of the most basic formulations of the human/machine/environment paradigm occurs when a microphone and amplification system is placed within an environment with a performer. An obvious starting point here might appear to be a work such as Stockhausen's *Mikrophonie I* (1964), in which he uses the microphone like a microscope, to amplify "normally inaudible vibrations" produced by playing a tam tam in various ways (Stockhausen, 1971). The score contains stochastic mechanisms and at first glance the piece appears to conform to a human/machine/ environment paradigm. However, despite Stockhausen's conception that "the microphone is used actively as a musical instrument, in contrast to its former passive function of reproducing sounds as faithfully as possible" (Stockhausen, 1971), the piece fails to live up to this promise. This is for two specific reasons: firstly the microphone is a passive tool, it is merely capturing the sounds. While filters are used to alter the captured sound and this element is a human/machine interaction, the environment plays little or no conceptual role in the resultant sound of the piece; the only factor here is perhaps the choice of microphone, its placement, and the choice of amplification, and all of these facets point to the microphone being a tool, not an instrument in its own right. Secondly, the environment plays little or no role in the aleatoricism of the composition; instead this is conceptually determined by the score and the performer. In summary, there is no feedback loop. The performer is not reacting to the resultant sound, but reading from a score and thus the piece consists of the interaction of a number of determinate, closed systems, not the open system that would arise with the inclusion of the environment as an integral part of the composition.

In contrast, composer Robert Ashley's *The Wolfman* (1964) uses a microphone in a way that incorporates the environment as a core component of the sonic and compositional superstructure of the piece. *The Wolfman* is performed by placing a microphone in an environment and amplifying the signal with a P.A. system, which is driven to the point of feedback. The performer 'sings' a series of vocalisations while at the same time modulating the resultant feedback tone by changing the shape of the mouth around the microphone. Accompanying material is also played on tape during the performance. Ashley states:

> "In *The Wolfman* the feedback is tuned for whatever place you're performing in. Then into that feedback are put different kinds of modulating material on tape. That modulated feedback product is passing through the sole microphone in the space, the singer's microphone. That means by just putting your mouth up to against the microphone, and by doing simple vocalisms, you can affect that whole feedback system in a very slow, modulation filtering sense. That's the principle of the piece. The feedback loop and the tape sound is being broadcast into that loop. The bottleneck in that loop is the microphone so that by treating the resonant cavity right in front of the microphone you actually create a model of the room in the size of the vocal cavity. It's a very simple principle. The room just keeps moving around and changing shape because of the way you shape your mouth" (Ashley in Holmes, 2012).

Ashley's conception of the microphone is very different to Stockhausen's. Here the use of the microphone is a central determinant in the resulting sound of the piece, the 'bottle neck' – as Ashley puts it – that closes the performance feedback loop.

A slightly different, but no less cybernetic conception of the microphone as instrument – and thus one that allows the inclusion of the environment in the compositional process – is Steve Reich's seminal feedback piece *Pendulum Music* (1968). In *Pendulum Music*, several microphones are suspended in a row above a number of speakers, which are on the floor, pointed upward toward the microphones. As the performance begins, the amplification system is pushed to the point of feedback and each microphone is swung over the speakers creating an audible feedback 'whoop' or tone each time it passes directly in front of the speaker. This creates a sequence of feedback tones whose timing is dictated by gradually decreasing the velocity of each swing. The piece ends after approximately 10 minutes when each microphone comes to a halt and only one continuous, accumulative feedback tone can be heard. Reich describes the piece as "the ultimate process piece. It's me making my peace with Cage" (Reich in Holmes, 2012). It is clearly evident that the microphone and amplification system used in *Pendulum Music* are being utilised as a musical instrument, even producing pitched tones. Furthermore, the audible outcome of the piece is fully dependant on the acoustic nodes in the environmental space, which create the particular feedback resonances heard in each performance.

Before examining specific cybernetic composers in the following chapters of this thesis, the work of David Tudor (1926-1996) is very relevant to the idea of the incorporation of the environment into composition. Pianist and composer Tudor is known for being the long time associate and collaborator of John Cage. Tudor came to Cage's attention as an extremely accomplished concert pianist, performing the leading avant-garde pieces of the 1950s, including the first American performance of the *Piano Sonata No. 2* by Pierre Boulez in 1950. Tudor performed the premier of some of Cage's most notable works, including *Music of Changes* (1951) and *4'33"* (1952) (Holzaepfel, 2006). However, in the early 1960s, as his collaboration with Cage matured, Tudor became less interested in performing the piano and began to experiment with electronics. Tudor struggled to find his own voice as a composer. Nonetheless, it was through his technological collaborations with Cage in the 1960s, such as *WBAI* (1960), *0′ 00″* (1962), *Variations V* (1965), *Variations VI* (1966), and *Variations VII* (1966), that he found his impetus to compose electronic music (Pritchett, 2013*).* Tudor became a pioneering electronic composer, designing much of his equipment from scratch. Most of his work with Cage centred around amplifying found objects or instruments in an unusual way, as was the case with *Music for Amplified Toy Pianos* (1960). However, Tudor was also a pioneer of composing with circuit feedback, where the output of a device is fed back into its own inputs and the resultant audio can be manipulated by controlling filters and gain levels. Pieces such as *Untitled* (1972), *Toneburst* (1975), and *Pulsers* (1976) are prime examples of this type of electronic composition. However, while this way of working has many resonances with cybernetic composition, especially with the work of Louis and Bebe Barron, these works do not overtly incorporate the environment in the compositional process. Nonetheless, a number of other electronic pieces that Tudor composed or collaborated on do utilise environmental factors in their composition. One such piece is John Cage's *Variations V* (1965). *Variations V* is a multimedia 'Gesamtkunstwerk' incorporating dance, video and music. Composed in collaboration with Cage's life partner and choreographer Merce Cunningham, *Variations V* incorporates video work from Stan VanDerBeek projected into a space where Cunningham's dance troop perform and react to the surrounding environment. While the composition is credited to Cage, much of the technological apparatus that enabled the musical performance was envisioned and realised by David Tudor and Gordon Mumma. Mumma describes the performance set-up as follows:

> "The stage contains two systems of electronic sensors; the first is a set of focused photocells, the second a group of five-foot-high antennae. As the dancers move about the stage they interrupt the light, which falls on the photocells. The vertical antennas are capacitance devices, which respond to the distance of the dancers from each other, to the proximity of the dancers from the antennas, and the number of dancers on the stage. The changes of light intensity on the photocells, and the capacitive responses of the antennas, are both transmitted as electrical signals to electronic music 'trigger' equipment in the orchestra pit. The musicians operate an 'orchestra' of tape recorders, record players, and radio receivers, which contain the sound materials composed by Cage. Before these sounds are heard by the audience they are fed into the electronic-music 'trigger' equipment. The sounds are then released to loudspeakers in the audience by the triggering action of the dancers' movements on stage.
> Because the functions of these two separate sensor systems overlap, the correspondence of the dancers' movements on the stage and the sound movements in the auditorium are extremely complex" (Nyman, 1999).

In this instance, unlike in *The Wolfman* or *Pendulum Music*, the sound in the environment does not form part of the compositional superstructure. The sounds are derived from recorded materials. Nonetheless, other factors in the environment, principally the movement of the dancers, determine the structure of the composition, in this case by only playing snippets of recorded audio material when a dancer interacts with the photocells or the capacitance antenna.

Another of Tudor's pieces that had an overt human/machine/environment axis in its composition was *Rainforest IV* (1973). Tudor's "Rainforest" series also grew from a Merce Cunningham collaboration, in which small, 'sounding sculptures' were amplified using contact microphones. In *Rainforest I* (1968), small portable sculptures were created, which would vibrate when sound was played through them. This could be achieved by small speakers attached to the sculptures or via larger loudspeakers in the performance space. Contact microphones were attached to the sculpture and the resultant sound of the vibrations was fed back via a mixing desk to the loudspeaker. Thus the sculptures altered the nature of the amplified sounds being 'played through' them due to the different resonant materials from which the sculptures were made (Tudor, 1985). In the first incarnation of "Rainforest", Tudor used electronic oscillators that generated bird-like sounds. In the second incarnation he used vocal sound from a microphone, and in the third version he used sound scores from tape to vibrate the sculptures.

Rainforest IV was perhaps the most fully realised version of the original environmental resonance/feedback concept. Tudor states:

> "My piece, "Rainforest IV", was developed from ideas I had as early as 1965. The basic notion, which is a technical one, was the idea that the loudspeaker should have a voice which was unique and not just an instrument of reproduction, but as an instrument unto itself [...] In 1973 I made "Rainforest IV" where the objects that the sounds are sent through are very large so that they have their own presence in space. I mean, they actually sound locally in the space where they are hanging as well as being supplemented by a loudspeaker system. The idea is that if you send sound through materials, the resonant nodes of the materials are released and those can be picked up by contact microphones or phono cartridges and those have a different kind of sound than the object does when you listen to it very close where it's hanging. It becomes like a reflection and it makes, I thought, quite a harmonious and beautiful atmosphere, because wherever you move in the room, you have reminiscences of something you have heard at some other point in the space" (Tudor, 1988).

FıS 2. *Circuit diagram for 'sounding objects' in David Tudor's Rainforest IV: sourced from http://davidtudor.org/Works/rainforest.html*

It is clear from the above circuit diagram that *Rainforest* was a feedback system in which multiple sound sources, either from the original sound source (say a tone generator) and the contact microphone source (placed inside the sculpture) could be fed back in a variety of complex ways, either into, or out of, the initial sound source mixer, or into, or out of, the contact microphone mixer. This means, for example, that microphone source could be fed back into the speaker to reinforce the resonance of the sculpture, or that the resultant sound could be fed to multiple sculptures in the space, and vice versa.

With respect to "Rainforest IV", Tudor said: “the object was to make the sculptures sound in the space themselves. Part of that process is that you are actually creating an environment. The contact mics on the objects pick up the resonant frequencies which one hears when very close to the object, and then are amplified through a loudspeaker as an enhancement" (Tudor, 1985). Furthermore, Gordon Mumma reiterates the ecological nature of the piece: "the entire electro-acoustic apparatus [was] an ecologically balanced sound system" (G. Mumma in Warburton, 2000).

3.8 Conclusion

While there is no doubt that Cage, Tudor and Mumma were all exposed to cybernetics, and we shall examine some of this acquaintance in later chapters[7], they never claimed to be cybernetic composers. However, this does not mean that their work is to be ignored or their influence overlooked when considering cybernetic music, particularly when examining works that have an overt human/machine/environment paradigm of the kind that is prominent in some of the preceding works. We should also not ignore the importance of algorithmic and generative music in the formulation of cybernetic music. Indeed, some notable commentators such as Boden and Edmonds trace the lineage of generative music directly back to cybernetics (Boden and Edmonds, 2009). However, we must make a distinction here because as generative music implies an ecological/non-deterministic/non-hierarchical character, synonymous with cybernetic music, this ethos is largely absent from most forms of algorithmic composition, which are primarily concerned with mathematical operations not eco-systemic paradigms.

This is not to say that mathematics is absent from cybernetic music, far from it! However, the mathematics of cybernetic music tends not to be the probability-based calculations of Stockhausen, Xenakis and Cellular Automata, but the open-ended and sometimes paradoxical formulations of feedback, autopoesis and complexity theory.

So the conception of cybernetic music that follows is not one that is separate from the musical, scientific, mathematical, and technological continuum described above, rather it is one that is a very definite and defined example of this intermingling, with its own very particular set of beliefs and practices.

[7] Specifically chapters 5.2 Louis, Bebe Barron & John Cage, 5.3 Alvin Lucier, 6.2 Brian Eno & 6.3 Agostino Di Scipio and Iannis Xenakis.

Chapter 4

Musical Notation, Electronic Technology and Cybernetics: a Pragmatic Perspective

4. Musical Notation, Electronic Technology and Cybernetics: a Pragmatic Perspective

[Western art music's] assumptions are those of post-Renaissance humanism and individualism, and it has the characteristic virtues and limitations of that viewpoint. If we compare it with the music of the rest of Europe's history, not to mention that of the rest of mankind, it begins to look like something of an historical freak (Small, 1996).

Traditionally, composition has been a matter of notation and formal organisation. Conversely, many modern musical works that utilise electronic technologies do not rely on formal notational systems. This chapter makes the case for cybernetic compositional systems that do not adhere to traditional forms, and in particular, those that do not elevate notation or score as the ultimate musical artefact.

Three main areas will be examined: firstly, the pragmatic philosophical position as it relates to technology, which argues that text-based forms such as notation are unnecessary in works that utilise electronic media; secondly, the consideration of the value cybernetics may have as a systematic framework for musical composition with electronic technologies that does not require notation; thirdly, a mathematical explanation of feedback, as it pertains to cybernetics, and some description of how it may be incorporated both as a control mechanism and as an audio phenomenon in musical composition.

4.1 Musical Notation

The practice of composition since the Second World War has embraced electronic and non-musical technologies in an ever-increasing symbiotic relationship. The use of these modern technologies has in some cases undermined the necessity for traditional notation, particularly where pieces are either predicated by the technology – as is the case, for example, with Steve Reich's *Pendulum Music* (1968) – or where the piece is the result, not of formal musical experimentation, but of a 'non-musical' process, such as with Alvin Lucier's *Music for Solo Performer* (1965).

To understand the position of notation within these modern electronic works, and its relationship to what we might term the 'finished piece of music', it is useful to frame notation within a pragmatic philosophical context, in particular the notion of the technological means and the artistic ends. The philosopher Richard Coyne contends that: "Pragmatism advances the thesis that theory is a kind of practice. Pragmatism also embraces liberalism. In contrast to the Cartesian tradition, it also affirms embodiment and engagement of the senses in human experience. It also asserts the formative power of technology in human affairs" (Coyne, 1995).

First expounded by the philosopher John Dewey (1859-1952) and later expanded on by Marshall McLuhan (1911-1980) philosophy divides human interaction with technology into three broad epochs; the first epoch is the "pre-technological era". Here, means and ends are integrated; tools do not signify anything other than themselves and their use in achieving short-term goals.

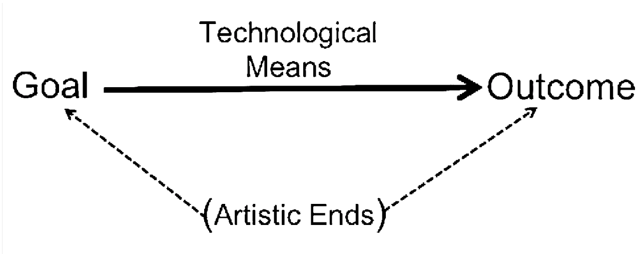

Fig. 3. A graphical interpretation of the relationship of means, ends, goals and outcomes in McLuhan's conception of the pre-literate society.

The forms preserved in pre-literate societies today exemplify music of this era. Here, music is not notated, but improvised. The act of playing music is often a transformative process as part of a rite or ritual (Coyne, 1995). Music is not only a product of practice; it is also a tool in itself. It provides both a means – of inducing altered states of consciousness in a battle trance, for example – and also mitigates the ends – for example, of forming a collective identity and battle cry when advancing into conflict (Jordania, 2006). Here, music is formed as group activity, where the music-makers and the audience are one in the same. Meaning is derived by collective action and interpretation.

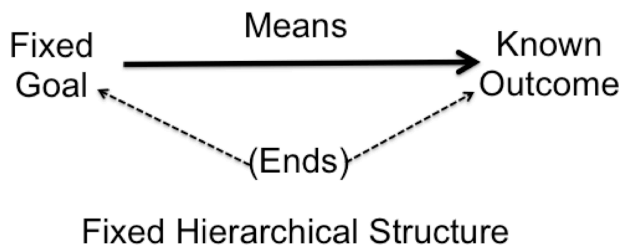

Fig. 4. A graphical interpretation of the relationship of means, ends, goals and outcomes in McLuhan's conception of the literate society.

The second epoch is the " technological age" (the literate society) in which means and ends are separated; means are subservient to ends and text is the dominant technology of this era. This separation of means and ends begins with Plato's abstractions of perfect forms and is perfected in Cartesian Dualism (Coyne, 1995). Music of this era begins with the abstraction of musical notation and culminates in the romantic era of the nineteenth century. Here notation and instrumentation are the technological means. However, the technology in itself seldom mitigates the ends, it merely facilitates the ends. The end is not only the piece of music; it is also the intended emotional significance. Dissemination of meaning is seen to be hierarchical: imbued by one individual, namely the composer, for interpretation by musicians and subsequently an audience.

The third age is the current " scientific/electronic era". Here, means and ends are partially reunited. Means may now direct process and point to new discoveries. In the modern era, according to the pragmatic philosopher Larry Hickman, "Theory became a tool of practice and practice a means to the production of new effects. Theory no longer had to do with the final certainty but instead, as working hypothesis, with the tentative and unresolved" (Hickman in Coyne, 1995).

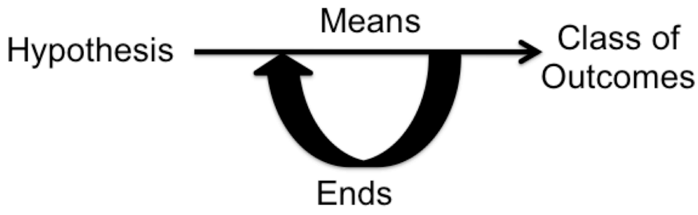

Fig. 5. A graphical interpretation of the relationship of means, ends, hypothesis and outcomes in McLuhan's conception of the post-literate society.

In the scientific/electronic paradigm, the means mitigate the ends and in some cases they converge with no single entity taking precedence in the creative process. Electronic and digital tools are the dominant technologies of this era (Coyne, 1995). Music of this epoch is mitigated by electronic technologies, which take precedence over notation as a way of recreating a musical experience in another time and place, and in some cases, the electronic means utilised within a composition mitigate the outcomes to such an extent that the "medium becomes the message". In this type of musical work, meaning is no longer disseminated hierarchically, but is more often formed by a negotiation – between the composer, technology, and the audience.

Marshal McLuhan believed that with the invention of the Gutenberg printing press, Renaissance man had traded "an ear for an eye" (McLuhan in Coyne, 1995). With the invention of the telegraph, however, McLuhan asserted that humans had shifted back into the aural-acoustic world, which he termed the 'post-literate society'. He further postulated that the post-literate society shared many characteristics with the pre-literate society, stating that in the second (rational) epoch, the visual sense was dominant, but in pre-literate and post-literate societies, the auditory sense is foremost (Coyne, 1995).

It is therefore reasonable to assert that in the post-literate society, notation (musical text) is no longer the dominant technological means in the compositional process, but merely a tool that may be selected from a series of options. In many cases, particularly where technology mitigates the end result, notation is often redundant, both as a creative tool and a storage medium for accurate reproduction.

"For McLuhan, in the electronic era 'the action and the reaction occur almost at the same time'. Electricity produced a great historical reversal in making things instant again. 'Electric writing and speed pour upon humans, instantaneously and continuously, the concerns of all others are known and we become tribal once more; the human family becomes one tribe again within the global village" (Coyne, 1995).

It is perhaps no coincidence, therefore, that within this context the type of improvisational forms found within pre-literate societies have seen a resurgence in modern times (Cee, 2010); free improvisation, jazz and new approaches to classical music may all be seen as part of this milieu. The burgeoning use of graphical scores may also be seen as part of this paradigm. Here, the usurping of the technology of traditional notation sees the blurring of means and ends, which mirrors the way in which electronic technologies are often utilised to the same effect within composition.

4.2 Cybernetic Design and Music

It is important to distinguish, however, between certain musical practices that employ technology, as many of these still point toward the logocentric, technological age, while others adhere to the less hierarchical scientific/electronic model. Creative musical works that utilise electronic technologies tend to fall into two broad camps, which (to borrow from the terms of Stafford Beer), I shall refer to here as the 'reductive technological paradigm' and the 'generative technological paradigm' (Beer, 1994).

In the reductive paradigm, all the parameters of systems that employ electronic means in the compositional process are predesigned and orientated toward a known goal. These systems seek to eliminate problems such as circular causality and paradoxes. Their aim is to produce 'perfect' structures (in the Platonic sense) that reduce or eliminate errors. This approach stems from traditional, formal, score-based composition and (in electronic terms) is related to the field of artificial intelligence. The field of music informatics exemplifies this paradigm. Here, musical parameters – notes, frequency information, or metadata – are reduced to representational information that may be manipulated for the purposes of score design, analysis, mimicry, recognition, or categorisation. Technology is employed as a means to an end, with the conceptual priority on the achieving of the ends. The technology is only a tool in producing the end result (Coyne, 1995).

To provide some concrete examples, this might be, for example, a composer utilising the Sibelius sequencing software to produce musical works, or a computer program that can recognise the works of specific composers and can also imitate such work, or a software program that can recognise melodies, harmonies or lyrics and cross reference these with a library of recorded works. This field also encompasses some forms of systematic composition, particularly those with fixed goals.

It is notable that in all these cases, the emphasis is on pitch over timbre and that the act of composition is achieved solely via human intelligence; compositional parameters are seen as being conceived by human agency alone with specific human goals. This is a 'top-down' process, where all the structures within the system are defined by the composer and controlled to produce a fixed result. This is a closed system paradigm, in which environmental factors are conceptually expunged. If the composer or software designer wishes to approach anything like intelligence within the software design (as is the case in recognition and mimicry), it is a very computationally expensive process (i.e. it uses large amounts of memory, or is concerned with large data sets), as all possible parameters within the compositional system must be known beforehand.

Conversely, the generative paradigm involves the symbiotic process of music creation between the technology and the composer. It embraces circular causality as a central tenet and sees errors as a vital part in any system's capacity to learn. Here, the means mitigate the ends and in some cases they converge, with no single entity taking precedence in the creative process. According to Brian Eno, this is a 'bottom-up' approach, meaning the systemic or technological aspects act as a 'seed' that will 'grow' the composition, in opposition to an Artificial Intelligence approach where the entire 'tree' must be known in advance (Eno in Toop, 2004).

This compositional approach is related to the field of cybernetics. Here, the control of the output is not imposed from 'above', in a hierarchical formation, but is instead achieved through a balance of control between all parts of the system. Examples of this type of approach would include a composer influencing an algorithmic process in real time, the layering of sound in a non-linear, semi-randomised process, or soundscapes that react to changes in the environment in which they are embedded (Toop, 2004). These works are often reflexive or self-referential and outcomes are not fixed but instead adhere to a "class of goals" (Beer, 1994), that is to say that these musical systems can produce unintended or unpredictable outcomes, but each iteration (each run of the system) maintains enough sonic coherence to theoretically allow a listener to identify it as *that* particular piece of music.

Heuristics are a device that is often employed in this type of creative enterprise. These are not algorithms or an aleatoric processes; they don't produce set results or chance outcomes, but rather results that are unpredictable, but which adhere to a 'class of goals'. Here, errors are not seen as anomalies to be expunged from the process (as in A.I.) but as a vital part in any creative or learning process (Beer, 1994).

According to Stafford Beer, a good way of describing an heuristic would be to imagine that you wanted to go to the top of a mountain. If you were to do this using a system like artificial intelligence, you would have to describe every obstacle, every rock or nook or cranny of the mountainside and provide an appropriate map, requiring a huge amount of information. Alternatively, if you were to use an heuristic, you'd simply give the instruction "keep going up" and this modest command would bypass the need for all the extraneous information about the environment. Only feedback from the environment encountered in the runtime of the heuristic would be pertinent. Therefore, an heuristic is a very simple set of instructions that adhere to a known criterion, which can be evaluated and revaluated as you go along, to achieve a class of outcomes (Beer, 1994).

4.3 Feedback

Generative and real-time compositional processes often adhere to this heuristic, environmentally-coupled model. Central to these modes of composition and more pertinently to cybernetics is the concept of the feedback loop. Feedback is the mechanism by which a system is able to reinforce or suppress stimulus without prior knowledge of the environment. In a living organism, a "criterion of stability" (Ashby, 1952) is embedded in feedback mechanisms and this allows for the possibility of autopoiesis (a self-sustaining organism). Thus, feedback mechanisms can demonstrate characteristics of intelligence; however, the amount of data needed to create this type of command-and-control structure is extremely minimal (Beer, 1994).

Feedback loops are central to many engineering systems. One such example is a lavatory cistern, which is a very simple but effective feedback loop; as the handle is flushed, the ballcock sinks to the bottom of the tank, thus opening a valve that fills the tank again with water. When the ballcock floats to the top of the tank on the ascending tide of water, this closes the valve. According to Beer, a system such as this 'knows' nothing of its environment but its behaviour exhibits some minimal characteristics of intelligence (Beer, 1994).

A cybernetic system is one that can react to environmental stimuli and adapt to achieve internal stability. However, it is important to make a distinction between an organism or machine being 'aware of itself' and being 'self-conscious'. In his elucidatory book *Brain of the Firm* (Beer, 1994)[8], cybernetician Stafford Beer asks us to "define awareness behaviourally" (Beer, 1994). Ashby states "machines are what they do" (Ashby, 1953). Beer further argues: "We define an assemblage of entities as a system because they appear to be acting cohesively." If the system responds to stimulus, "then we can say it is aware". Stimulus is defined as something that "alters the operation of the system" (Beer, 1994). Beer is also careful to point out that a system does not require *knowledge* of the environment to react to stimulus, as this is only registered internally. In general, "a system avoids or otherwise counteracts stimulus which disrupts its activity, and embraces or seeks to increase a stimulus which favours its activity" (Beer, 1994). He further postulates: "responses to stimuli by aware systems are either negative or positive […] It follows that the aware entity has, in some sense, the ability to judge which is which" (Beer, 1994). A system's criterion of smooth operation is based on *internal* stability. If we shrink away from a burning flame it is because the pain exists *inside* us; it upsets our internal environment. It might be intuitively presumed then that because organisms are able to categorise stimuli and *know* in advance of environmental dangers or advantages that this must be an essential component of designing viable systems and machines (especially to protect against unforeseen circumstances). "All this is mistaken", asserts Beer. All a system requires is "a way of measuring its own internal tendency to depart from stability, and a set of rules for experimenting with responses which will tend back to an internal equilibrium" (Beer, 1994). In cybernetics, a system that can survive arbitrary and un-forecast interference is known – in Ashby's terms – as an 'ultrastable' system (Ashby, 1952). An ultrastable system survives not by perceiving external threats, but by adhering to its own internal check system. We can conclude from this that 'intelligent' systems are often very simple and may have the appearance of conscious thought, but are in fact non-conscious entities, incapable of external perception.

[8] Beer's Book *Brain of the Firm* was originally published in 1972. The version referred to here is the revised and reprinted 1994 edition.

In order for a system to be self-regulating, feedback mechanisms must be employed. Beer states: “what the term (feedback) means strictly is so fundamental to cybernetic thinking that its connotations should be unravelled with some care”. He defines feedback as “the return of a system’s output to its input, which is thereby changed. Positive feedback takes an increase in output back to increase the input; negative feedback takes back an output increase to decrease the input and is therefore stabilizing in principle” (Beer, 1994).

In the terms of this thesis, it is conceptually important to state that almost all audio applications and in particular DSP processes utilise feedback as a mechanism of operation. This is particularly true of those that incorporate delay, such as filters, equalisation, reverb, delay lines, compression, etc. A basic example, in audio terms, is a typical feedback delay circuit (such as in Fig. 6), which consists of a signal input (*i*) and an output (*o*). A delay line is placed between the input and output (*Delta t*) and a feedback line is routed from after the delay, passed through an amplifier (*) and fed back into the signal line before the delay circuit, which allows addition or subtraction of amounts of feedback from the signal. This type of circuit can produce several effects (depending on the amount of delay time and feedback); typically it is known as a feedback delay but with shorter delay times it is also a flanger, or comb filter (Davis & Jones, 1990).

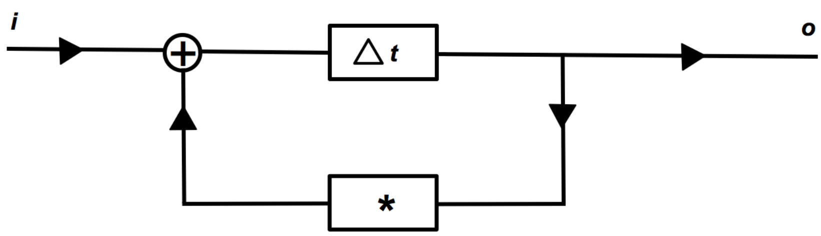

Fig. 6. A feedback delay circuit (modified from Davis & Jones, 1990)

The delay line minus the feedback line will only produce a single repeat of a sound signal. However, if the feedback path is added, multiple repeats are possible. The larger the volume of the feedback path, the greater the output volume and number of repeats.

The universal feedback circuit Beer describes in *Brain of The Firm* (Fig. 7) is one that is commonly found in electrical and control engineering. It is capable of producing positive or negative feedback (reinforcing or negating stimulus). It is also “a self-regulating mechanism which does not rely on understanding *causes* of disturbance but deals reliably with their *effects*” (Beer, 1994). This is significant, as it stands in opposition to many of the symbolic representation models in A.I. research, which tends toward symbolic representations of *knowing* causes in order to react.

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Fig. 7. Beer's Feedback Network (Beer, 1995, 34)

Fig. 7 displays a feedback network: Two 'switch' mechanisms are embedded in the circuit: $f(p)$ between the input and the output (on the forward line) and $F(p)$ on the feedback line. An input signal *i* will pass through $f(p)$ and be fed back via $F(p)$ and added into the signal at X. So *e* can be defined as:

$$e = i + oF(p)$$

In operation, the value of *e* is passed back through $f(p)$ and through to the output *o* (and also back through the feedback line). Before examining this circuit further, it is important to explain the nature of the 'switches' $f(p)$ and $F(p)$. The term 'switches' is used here as they are indeed 'deciding' mechanisms. However, this is not based on a simple yes/no decision or an on/off switch, but instead on a 'sliding scale' mechanism known as a 'transfer function'. A transfer function in electrical engineering (and indeed audio engineering) is typically some sort of amplifier (this may be linear or non-linear). To demonstrate the circuit practically, we could imagine that the input *i* had a value of 2. We might then imagine that $f(p)$ was amplifying the signal (multiplying it) by 2. This would give a result of 4 at o. Now let us imagine that we wished to regulate the circuit so that no matter what the input, it would always be equal to the output. To do this we could add the value of 0.5 into the $F(p)$ amplifier (multiplier). This would have the effect of halving $f(p)$ and thus returning input and the output to unity. There are a number of things to be said of this practical demonstration. Firstly, it is easy to see how positive and negative feedback can be generated (assuming that the value of $f(p)$ is always larger than 1. Values of less than 1 in $F(p)$ will generate negative feedback (suppressing the signal), while values greater than 1 will produce positive feedback (massively amplifying the initial input). Secondly, it is important to emphasise that the above example is only a snapshot of a system at a fixed point in time. In reality, feedback systems are fluid and dynamic and amounts of suppression or amplification are determined by the 'sliding scale' transfer functions within $f(p)$ and $F(p)$. This means that at any constantly changing input value, the level passing through the transfer functions will determine whether feedback is positive or negative, automatically boosting or attenuating the signal based on the value of the transfer function. Beer further defines the transfer function of the whole system as: $\emptyset(p)$ (Beer, 1994). To calculate this value we can use the equation:

$$\emptyset(p) = \frac{o}{i} = \frac{f(p)}{1 - f(p)F(p)}$$

As has already been stated, the above equation will yield a model of a circuit capable of providing positive or negative feedback. However, if we wish to have an error-correcting circuit only (so that the circuit always produces negative feedback (as in mainly the case in control engineering), this may be changed by subtracting the value of the 'error' (e) transfer function from the original input:

$$e = i - oF(p)$$

This changes the overall equation of the transfer function to:

$$\emptyset(p) = \frac{o}{i} = \frac{f(p)}{1 + f(p)F(p)}$$

Thus: "The reciprocal of the transfer function of the feedback network determines, all by itself, the overall transfer function of the system" (Beer, 1994).

In engineering or biological contexts, an input signal may need to be amplified greatly in the forward line, but this inevitably leads to any noise or error in the signal also being amplified. However, with the negative feedback circuit described above, the feedback network automatically attenuates any error, leaving only a pure signal to pass through the circuit. According to Beer this is a central mechanism for 'ultrastability': "Negative feedback corrects any output in relation to fluctuating inputs from any cause. It does not matter what noise gets into the system, how great it is compared to the initial input signal, how unsystematic it is, nor why it arose. It tends to disappear" (Beer, 1994). This method is also precisely how noise is removed in audio amplification circuitry.

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Figure 6

Fig. 8. Ashby's model of 'the simplest version of a controller.' (Beer, 1994)

Ashby's model of "the simplest version of a controller" (Beer, 1994), extrapolated from Ashby's *Design for a Brain* (Ashby, 1952), describes the control function of an ultrastable system. It is utilised to demonstrate a practical implementation of the above principles. Here we see a simple feedback mechanism, which is defined by a 'criterion of stability' (C of S). Stimulus enters via transducers (note, microphones are also transducers), which is registered by a 'sensorium'. This acts according to a criterion of stability, and sends either a positive or negative signal to an 'effector', which acts to either repel or attract the stimulus. To explain further, "a sensorium is anything within a system that can register and classify the existence of stimulus" (Beer, 1994). It measures the amount of stimulus against a criterion of stability. For example, if this were a temperature scale then 'very hot' or 'very cold' would be registered as 'pain' or 'danger' by the C of S, which would then set the switch to 'avoid' at these extremities and 'attract' in the 'comfortable' zone. To decide between A and B the system must compare outcomes of making either choice against the C of S. "To do this, its simplest strategy is to do a *little* avoiding and a *little* reinforcing, testing out the results on its criterion, and then firmly setting the switch. Error is an important and necessary part of decision-making and a vital element in the creation of a stable system. It is worth noting that if experimentation goes on too long, the system will go into oscillation. All systems are prone to this phenomenon, in engineering it is called 'hunting' and in physiology 'ataxia'" (Beer, 1994).

4.4 Variety and Recursion

In addition to the notion of feedback, Beer introduces us to some further "conceptual components" essential to the understanding of cybernetics. These include 'heuristics', 'variety', and 'recursion'. As we have already noted, Beer defines an heuristic as "a set of instructions for searching out an unknown goal by exploration, which continually or repeatedly evaluates progress according to some known criterion" (Beer, 1994). It is important to note that this is in contradiction to an algorithm, which "is a technique for, or mechanism, which prescribes how to reach a fully specified goal". An algorithm will produce a fixed outcome, whereas an heuristic will produce an outcome within a "class of goals". Beer further elucidates that "heuristics prescribe general rules for general goals". To return to his axiom, which is so critical in terms of cybernetic musical composition, it is in connection with how heuristics work when interacting with complex systems that he states: "instead of trying to organize it in full detail, you organize it only somewhat; you then ride on the dynamics of the system in the direction you want to go" (Beer, 1994).

In complex systems, the amount of external stimulus flowing into an agent can be very large. We have seen how noise/error can be reduced but even allowing for this function, the sheer amount of pure information being input, processed and output from a system can be incomprehensibly vast. In cybernetics, the term 'variety' is used to describe "the total number of possible states of a system, or of an element of a system" (Ashby, 1952). According to Ashby's 'Law of Requisite Variety', "control can be obtained only if the variety of the controller (and all parts of the controller) is at least as great as the variety of the situation to be controlled" (Ashby, 1952). Variety must also incorporate error. This poses a problem in engineering terms, as the internal variety of the system must 'mirror' the external situation, creating large, complex, and inefficient control systems. So, in order to maintain operation of accurate and complex perception, decision-making, and action processes, ways of reducing variety must be found, if efficiency is to be achieved. Beer cites the Algedonode (Beer, 1994), a cybernetic machine of his own creation, as a mechanical example of such a feedback circuit, which effectively reduces complex variety and produces 'correct' responses to dynamic circumstances. Analogous to this, in audio technology, the act of recording sound (by analogue or digital means) very effectively mirrors the external sound environment and reduces variety to manageable states, in what Shannon terms 'redundancy' (Shannon, 1948 & 1951). Once audio information is captured in this way (particularly in digital form), it can be measured and manipulated to produce (via measurement and manipulation of DSP) responses or desired outcomes. Audio processors may also be considered as variety reducers or amplifiers. For example, an audio filter can greatly reduce the variety of an audio signal, while harmonic distortion will increase it.

So, in thinking about the cybernetic design of electronic music composition systems, we may envisage a method of recording and means of signal processing that interacts with the environment in real time. The concept of 'recursion' is also important; in the context of designing such a cybernetic system, this pertains to a recursive coupling, in which, by a series of feedback loops, all components of a system (including those that route out to – and back from – an environment) are linked; a change in one area of the system will affect all components of the system by incremental interlinked degrees. Thus each element is recursively linked and no one element of a system exerts overall control. Within such a system, switches (or criterions of stability) may be set to reinforce or suppress stimulus, based on a continuous feedback process, which tests the composition for certain oppositional parameters. This is a dialectical, conversational process that exists within an environmental context. These operational parameters may be derived from measurements of information from the soundworld, such as amplitude, frequency, rhythmical content, etc. These parameters may then be compared in relation to each other and linked together to form a matrix of control functions; a change in one area may indicate the need to adjust another compositional component. Via this process, the machine may shape this material into a compositional structure, either independently or with human interaction.[9]

It is also important to emphasise that, in general, cybernetic works of music are ephemeral and each iteration is unique. Musical works are formed in real time as they interact with an environmental space, and the act of composition tends to be in the composition of the interactions between human, machine, and environment, with the aim that these interactions produce emergent behaviours that may be heard as music (Di Scipio, 2003).

4.5 Representational Versus Non-representational Systems

The above examination could conceivably beg the question, why bother to take the cybernetic route to making a compositional system, rather than the well established, symbolic artificial intelligence approach? Firstly, musical notation is a good tool to use with computers if one wishes to produce music that adheres to the traditions of Western art. However, as Denis Smalley and others have pointed out, notation is a poor descriptor of many modern electronic musics (Smalley, 1997). This is particularly true when the medium mitigates the message in a technologically symbiotic creative process. It is perhaps then pertinent to look to metadescriptors

[9] A pertinent description of such a system is to be found in Chapter 6.3 of this thesis, in the section on Agostino Di Scipio.

(beyond notation) that speak to common systemic control factors in a human/machine/environment paradigm.

Secondly, as Douglas Hofstadter points out, artificial intelligence is not able to solve the problem of computer compositions sounding creative or original (Hofstadter, 2007). Furthermore, according to the technological philosopher, Richard Coyne, computer interfaces are also very poor at interacting with human behaviour in a meaningful or creative way (Coyne, 1995). There are some good reasons for this, with the lack of feedback mechanisms in many A.I. systems, the inability to creatively utilise 'error', and the Cartesian dualism that permeates much of this research, to name but three. Finally, A.I. makes systems based on the Cartesian paradigm function more 'efficiently', whereas cybernetics focuses on sustainability, which encapsulates the creative act and creativity as fundamental elements. So in order to create a self-sustaining musical system that can respond to its environment and interact with a composer in a meaningful way, we must turn to the more pragmatic approach that cybernetics offers.

To summarise: New forms of compositional structures are akin to pre-literate forms of musical practice, where performance and process are mediated by technologies, and ends or outcomes are not fixed but held within a frame of ritual or ontological beliefs. Within this context, the technology of notation can be seen as the dominant technology of a past era and not of the current time. New technologies are directing us toward an expanded musical epistemology and an ontology that is more akin to the pre-literate society than the literate.

Composers such as Lewis and Bebe Barron, Herbert Brün, Roland Kayn, Brian Eno, Agostino Di Scipio, Gordon Pask, Iannis Xenakis, and John Cage, amongst others, have laid the theoretical and creative foundations for utilising cybernetics within musical composition. Cybernetics offers an engineering framework that allows composers to design electronic musical systems that are meaningfully interactive or self-creating without needing to utilise notation. It also adheres to a pragmatic position, which sees the blurring of means and ends in the compositional process. A.I. views computers as tools – the artificial thinking-machine is a subservient entity. Cybernetics offers an alternative view, one in which computers can be vibrant, symbiotic entities that may partner us in our creative acts, assisting and enhancing our creative endeavours in reflexive, innovative, and interesting new ways.

Chapter 5

First Order Cybernetic Music

5.1 Norbert Wiener – Cybernetics and the Inception of Electronic Assistive Audio Technology

We know that for a long time everything we do will be nothing more than the jumping off point for those who have the advantage of already being aware of our ultimate results (Wiener, 1953).

This examination of Norbert Wiener's (1894-1964) involvement with the development of the 'hearing glove' is something of an aside from the main purview of this thesis, which is concerned with musical composition. However, it is an important perspective to consider, as it demonstrates an interlinking of cybernetics and audio technology at an early stage in the development of both fields. Assistive technology is important in the context of this thesis in relation to the Human/machine/environment paradigm of cybernetics and the implications this has for music composition.

Music making is intertwined with tools and technologies, from instrumentation to notation. Though we may imagine a Platonic, idealised musical piece in the mind, in the attempt to realise it in the real world, it becomes mediated by many contingent conditions. Even a-cappella vocal singing is mediated by environmental factors and social or musical conventions (such as the aforementioned technology of notation). These contingent conditions can alter the Platonic idea of the music in unforeseen and unpredictable ways. We may say that the 'idea' of the music becomes somewhat subject to probabilistic processes in its translation from the mind to the finished work. In thinking of this phenomenon, one might assume that the more contingent or 'abrasive' the mediating technology, the less fluid it is at 'translating' our idealised form, and thus the more probabilistic processes come into play in this translation. Thus, there exists a tension between the imagined and the realised, and this dichotomy comes into sharp relief when we consider how machines assist us in creating music.

A common conception in music composition that utilises technology is that the machine perfectly assists the user in realising imagined pieces of music and that probabilistic processes are not an issue in any 'translation' process. In examining the extent to which technology may introduce probabilistic processes into compositions, it is worth considering assistive technologies that aid severely disabled composers; here the focus of how a technology is assistive is at its most pertinent and much might be considered about the degree of mediation or translation involved in the design of such a system. An example here might be using voice recognition to trigger a music-sequencing package. While this technology might be enabling in the sense that it 'gets the job done', the process itself might be very laborious and time consuming. The rigidity of the machine might well constrain the possible options. We might also consider that in this model the technology is not an equal partner, it is merely a subservient tool, a means that only exists for the ends. There is very little that is adaptive or reflexive about this technology.

Another factor that needs to be considered with the voice-triggering example is the extent to which the technology is replacing a part of able-bodied functionality. This question is important as it points to where much of the thinking behind this type of assistive technology comes from, which is deeply rooted in Platonic ideas concerning ‘perfect forms’ and the mind/body split that is synonymous with Cartesian dualism. So rather than ‘accepting’ the body as it is, the technology seeks to force the functionality of the physique; to make the body be of comparable ability to one that conforms to an idea of a perfect form. This thinking also elevates the mind over the body; the body is a tool that can manifest ideas that correspond to internal perfect forms in the external world.

Clearly, these aspects of assistive technology present us with some problems, particularly when we move beyond designing tools with clear-cut goals and begin to consider technologies that might drive process and point toward new creative possibilities. ‘Straightforward’ tools are useful and have a justified role to play in assistive technology, but they are not akin to technologies used in many scientific applications. According to Marshal McLuhan, in the scientific/electronic era, we see the blurring of means and ends, where the technology has the ability to direct process and point toward new conclusions and discoveries (Coyne, 1995). A good musical example of this type of technologically-driven process in music making would be Alvin Lucier’s *I am Sitting in a Room* (1969), where the technology and the environment mitigate the outcome to such an extent that ‘the medium becomes the message’. What is imagined by the composer may only be realised through the enframing power of the technological and environmental milieu; the sound of the piece and the composer’s intensions are wilfully at the mercy of these conditions.

In order to improve human/machine interaction in music making, it is worth revaluating the design and use of creative machines that assist process. A new framework is needed for this type of endeavour, one that embraces circular causality, breaks with the Cartesian tradition, and points toward new creative possibilities. Cybernetics offers us a constructive way of examining these issues. Indeed, as shall be demonstrated, cybernetics lies at the core of much of the thinking behind the first electronic assistive technologies that were designed for audio applications.

One interesting consequence of applying cybernetic principles when studying systems is that boundaries between entities can become buried or broken down; when one conceptualises information, control, and communication as an integrated system, entities may no longer be separate but seen as part of a unified whole. This idea is most pertinent when we consider the boundaries of the human subject. The anthropologist and cybernetician Gregory Bateson pondered this conception of boundaries when he considered the question, “Is a blind man’s cane part of him?” (Bateson, 1972). In general we would consider human boundaries to be defined by epidermal surfaces. However, N. Katherine Hayles asserts, “cybernetic systems are constituted by flows of information. In this viewpoint, the man and the cane join in a single system, for the cane funnels to the man essential information about his environment.” This viewpoint is the same as when we might consider a “deaf person's hearing aid, a voice synthesizer for someone with impaired speech, a helmet with a voice-activated firing control for a fighter pilot" (Hayles, 1999) – and for that matter, a music ecosystem capable of autonomous composition and reflexive interaction with performers.

We might observe in the above list of assistive technologies that it moves "from modifications intended to compensate for deficiencies to interventions designed to enhance normal functioning" (Hayles, 1999), and that this transitional list further demonstrates how conceptually difficult it is, from a cybernetic perspective, to draw distinctions between these categories. However, one of the founding fathers of information theory and cybernetics, Norbert Wiener, considered that it was critical to draw distinctions between certain types of assistive technologies; namely those that fall into the categories of being either ‘good’ or ‘bad’ machines. In his book *The Human Use of Human Beings* (Wiener, 1950), Wiener states that machines become evil when they are rigid and inflexible. "The ultimate horror is for the rigid machine to absorb the human being into itself, co-opting the flexibility that is the human birthright" (Hayles, 1999). By contrast, the cybernetic machine is flexible and adaptive, maintaining homeostatic stability in the face of all-consuming entropy. For Wiener, the "cybernetic machine is ranged alongside man as his brother and peer" (Hayles, 1999). The cybernetic machine reinforces rather than threatens the autonomous self: "when boundaries turn rigid or engulf humans they lose their agency, the machine ceases to be cybernetic and becomes simply and oppressively mechanical" (Hayles, 1999). And thus we see the paradigm of the repetitive and restrictive vs. the symbiotic and enhancing.

Cybernetics is a science of analogy and metaphor, the most pertinent one being that ‘living organisms are like machines.’[10] This analogy can be demonstrated from an information perspective; analogical relationships can be constructed between living and mechanical systems that demonstrate similar patterns of information and behaviour. It is important to recall that in cybernetics, “Analogy is not merely an ornament of language but a powerful conceptual mode that constitutes meaning through relation” (Hayles, 1999). It also allows us to cross boundaries and offers a powerful conceptual framework in design. Cybernetic machines are not merely compensating for lost behaviour; they are working symbiotically with human entities to enact new analogies or new approaches to outcomes.

Cybernetics lies at the core of the inception of electronic assistive technologies. In her paper “Cybernetics and Disability” (Mills, 2011), the academic Mara Mills writes: “Information theory and cybernetics emerged in a milieu committed to the materialisation and control of communication, rather than the ‘erasure’ of materiality and bodies. As a consequence, these fields prioritized certain kinds and arrangements of bodies above and beyond the sheer isolation or transfer of information” (Mills, 2011). “Early cyberneticians paid an obsessive attention to embodiment – through a policing of human difference that required as much physical labor as information exchange – as well as to physical media, which were evaluated in terms of their efficiency for carrying signals and their compatibility with human norms” (Mills, 2011).

Norbert Wiener’s ‘Hearing Glove’, was just such a cybernetic device. An early electronic haptic interface, it was developed in the electronics labs at MIT in 1949. Designed as an aid for deaf people, it converted sound waves into electromagnetic vibrations that could be felt in the fingertips. The hearing glove was built upon technologies such as the Vocoder and the Spectrograph that were developed at Bell Labs almost a decade earlier. The device was most notably associated with Helen Keller, who visited the MIT labs on a number of occasions to test the device. Wiener told Keller that the hearing glove was his first “constructive application of

[10] To paraphrase Wiener in Wiener, 1948.

cybernetics to human beings" (Keller, 1950). "The prosthesis Wiener designed can be understood as operating through analogy, for they transformed information from one modality into another" (Hayles, 1999). Machinic analogues were required to mediate between sensory domains. "The hearing glove was a 'strong analogy', a concrete analogue that replicated the speech processing performed by the inner ear. Although the glove was not a digital device (it did not quantize speech waves), it did filter the 'information' from the 'non-information' or redundancy in speech. This abstraction of information from speech waves was not abstract in the sense of being immaterial: the frequencies subtracted from the human-generated speech wave were transferred directly to other material media. Moreover, the information transmitted by the glove was defined with reference to certain physiological parameters" (Mills, 2011). Beyond tactile hearing, Wiener conceived of the glove as a feedback device to correct what he called the "grotesque and harsh intonation of deaf speakers" (Mills, 2011). He also suggested that these principles could be used as a basis for further work in sensory replacement. In his 1950 overview of cybernetics for the American Academy of Arts and Sciences, Wiener discussed the glove as a prime example of both feedback and information compression (Mills, 2011).

Fig. 9. Norbert Wiener using the Hearing Glove: https://arts.mit.edu/stefan-helmreich-discusses-upcoming-symposium-material/(2017)

Cybernetic music is rooted in questions about how technology might best assist us. In the hearing glove we can see a cybernetic model of an assistive technology that mirrors the use of cybernetics in electronic composition, one that utilises analogy to cross boundaries and operates in real time. It also works symbiotically with the user by filtering out unnecessary information in order to make the 'translation' experience seamless and un-rigid. The example of the hearing glove demonstrates that conceptions of technological interfaces and audio technology have been with us since the earliest days of electronic music. Yet, even today, the cybernetic model encapsulated in the hearing glove is rarely made explicit in electronic music. From this point forward, this thesis examines the story of cybernetics in musical composition and how these conceptions of non-subservient tools are becoming ever more accepted as common assistive technologies in this realm. The hearing glove points toward how a cybernetic machine might partner us in a creative endeavour and if we apply the spirit of these ideas to music composition this manifests in a rejection of perfect Platonic forms and an embracing of probabilistic processes; we may only realise the piece of music by interacting with the technology, the technology mediates the outcome in real time and therefore mitigates the outcome, driving process and pointing toward new outcomes.

5.2 Louis Barron, Bebe Barron & John Cage

In order to create electronic life, you have to be free to abuse the circuit
(Louis Barron in Greenwald, 1986).

One of the most prominent examples of cybernetic analogies being utilised with early electronic audio technologies is the work of Louis (1920–1989) and Bebe (1925–2008) Barron. These pioneering composers not only produced the first piece of electronic music to tape in America, *Heavenly Menagerie* in 1950 (Holmes 2002), they are also credited with creating music using cybernetic principles, most notably for the seminal 1956 science-fiction film *Forbidden Planet* (MGM, 1956).

Louis and Bebe originally hailed from Minneapolis and both studied music to degree level at the University of Chicago and the University of Minnesota respectively. After the couple met, they moved to New York and married in 1948. As a wedding present they were given a gift of one of the first tape recorders to be imported into the United States from Germany (Wierzbicki, 2005). Intrigued by the possibilities of this new technology, Bebe Barron recalls that they "did the usual experiments: slowing the tapes down, running them backwards, and adding echo" (Juno and Vale, 1994). To support themselves during the early 1950s, the Barrons opened a recording studio business in Greenwich Village that catered for the burgeoning New York avant-garde scene. This was the first electronic music studio in America and one of the first in the world, predated only by Schaeffer and Henry's studio at RTF in France (Holmes, 2002). Louis' expertise with electronics allowed him to expand the studio's equipment, building oscillators, speakers, and delay and reverb units.

Concerning the studio's technology, Bebe recalls: "We were using the same equipment that the classic electronic studios were using, although we were more limited because, number one, we were considerably earlier than most of them and we had to make a lot – in fact almost all – of our equipment. We were also limited financially because we didn't have an institution behind us" (Holmes, 2002).

Fig. 10. Louis and Bebe Barron in their Greenwich Village Studio in 1956 (Taylor, 2013)

After moving to California for a brief period, the Barrons refined their knowledge of the German tape machine by making recordings of a number of notable authors, including Anaïs Nin, Henry Miller, and Aldous Huxley. These were later released under the title of *Sound Portraits* on the Barrons' own record label (Wierzbicki, 2005).

The couple returned to New York in 1950 and quickly became part of the bohemian art scene in Greenwich Village, gaining a reputation for their work with sound and electronics. It was here that they met John Cage (1912–1992). At the time, Cage was predominately interested in utilising chance operations in his compositions. According to Holmes, Cage's interest in engaging chance procedures in his works had three main motivations. Firstly, to "create music for which the outcome was not preconceived – composition that was indeterminate of its performance" (Holmes, 2002). Secondly, to disengage "a composer from their natural instinct for making pretty music" (Holmes, 2002). And thirdly, to "remove the composer's taste entirely from the process of making composition" (Holmes, 2002). It was from this philosophical position, which on the surface appears akin to cybernetic precepts concerning order from chaos, that Cage proceeded to engage in composing by electronic means.

Cage contacted the Barrons to ask if they would act as sound engineers for a series of tape-based compositions that Christian Wolff, Earle Brown, and Cage himself were proposing. Cage had recently received a grant of $5000 from a young millionaire, Paul Williams, with which to achieve these experimental tape-based pieces (Wierzbicki, 2005). The most prominent work to emerge from these experiments was Cage's *Williams Mix (*1952). Cage conceived of the piece as a mix of environmentally recorded sounds that were to be spliced together on a series of tapes. The order, length, and dynamic contour of the recorded material were to be determined by his method of chance operations. Cage's favoured technique for producing random number sequences in this period was the I Ching, the ancient *Chinese Book of Changes.* He took the numbers generated by the I Ching process and assigned them as operators to determine different musical parameters within the piece. Cage stipulated that recorded sounds should be in six categories: city sounds, country sounds, electronic sounds, manually produced sounds (including musical instruments), wind produced sounds, and small sounds requiring amplification (Holmes, 2002). The recording and editing of the score was a major technical achievement, not least because many of the environmental sounds had to be recorded on location, not an easy feat with equipment that was far from portable (Holmes, 2002).[11]

Williams Mix took nine months of work to complete and saw its first performance in 1953 at the Festival of Contemporary Arts at the University of Illinois. The piece was performed using 8 tape recorders and was the first octophonic piece of music (Collins, 2010a). Its controversial reception can be heard in the raucous, mixed reaction it received from the audience at a notable recorded live performance at New York Town Hall in 1958, where applause and cheers can be heard mixed in equal measure with verbal disdain and displeasure (Cage, 1952). While *Williams Mix* was surely groundbreaking in its utilisation of technology coupled with random processes, it cannot be considered as belonging to a canon of cybernetic music. The

[11] See Fig. 10 for example, to the left of Bebe Barron.

academic Simon Biggs contrasts Cage's work of this period with that of Iannis Xenakis, and concludes that while Xenakis' work is derived from cybernetic principles, Cage's work by contrast may be "cosmetically similar", but it nonetheless derives from different sources of inspiration, namely that of neo-Dada, Fluxus, Eastern philosophy, Jazz, and traditional African music (Biggs, 1987), and as such it cannot be considered cybernetic in its inception. At this time, Cage's instinct toward chance operations also has a different impetus from the cybernetic recognition of probabilistic processes. Cage wished to remove the self, ego, and emotions from the compositional process, in order that it might be unaffected by the composer's memory or taste (Andrews, 2012). Furthermore, the influence of Eastern music and philosophy gave Cage his primary view of music's purpose, that of producing a "sober and quiet mind, thus making it susceptible to divine influences". This was in contrast to what Cage saw as the traditional view of music's purpose as "communication" (Cage, 1991).

While on the surface, some of Cage's aspirations appear to chime with a cybernetic compositional perspective,[12] for the cybernetic composer there is no overt desire to remove ego and emotions from the compositional process, rather there is a recognition that there are always probabilistic processes at play within the compositional process. The process of cybernetic composition focuses on the interaction of man, machine, and environment, and the information flow between the elements of the system and the composition of these elements take precedence over any musical notation or implied emotion imbued by a composer. There is also a recognition that there is no innate meaning within music and that the audience will imbue the work with its own meaning, therefore, the memory and taste of the composer does not need to be usurped; it is incorporated as an equal element in the compositional process, but it is by no means the primary focus.

And again, while superficially, it would appear that Cage's Eastern influence might find favour with many cybernetic composers, his view that music should produce a "sober and quiet mind, thus making it susceptible to divine influences" (Cage, 1991) is entirely absent from the cybernetic standpoint. And while some cybernetic composers, such as Brian Eno, produce music that could be said to induce such a state, others such as Roland Kayn distinctly do not. Nonetheless, in neither case can it be said that it is the intention of these cybernetic composers to produce music with an overt 'purpose' or implied meaning.

While it is almost certain that Cage had some familiarity with cybernetic ideas before the composition of *Williams Mix*, despite initial impressions, the piece itself is quite distinctly *un-cybernetic* in its compositional approach. Firstly, it is not designed to be ephemeral (a characteristic of almost all cybernetic composition and a trope to be examined many times in this thesis); the score attempts to define a consistent and repeatable piece of music, which theoretically, is the same in each performance. Secondly, the composition does not overtly include the environment in its performance; while environmental noises are used as the basis of the recorded material, no environmental factors are used as control mechanisms or live sonic inputs in the performance. Finally, the technology is used simply as a means to an end, as a tool to realise a text-based score. It is not utilised as a feedback mechanism,

[12] In particular, Herbert Brün's conception of anticommunication, as explored in chapter 5.4 of this thesis.

or as something that drives process and points to new discoveries: man, machine and environment are to a large extent kept separate in the compositional process.

By contrast, the Barrons' own compositional approach was overtly cybernetic. After completing *Williams Mix* in 1953, the Barrons gained a reputation for composing electronic music for films, most notably in collaboration with the film-maker Ian Hugo (husband of Anaïs Nin), and also in commercial advertising work (Holmes, 2002). These projects provided the opportunity for introductions to major Hollywood studio executives and in 1955 the Barrons gained their most important musical commission, composing the music and designing the sound effects for the seminal science-fiction film *Forbidden Planet* (1956). It was their work on this film that cemented their reputation as pioneering electronic composers and it also established their cybernetic compositional method.

Louis had a passion for electronics and the emerging field of sound synthesis and he saw these new technologies as fertile ground for creating new forms of musical expression. In the quest to design more sophisticated audio circuitry, he studied Norbert Wiener's 1948 book, *Cybernetics: Or, Control and Communication in the Animal and the Machine*. Here, Wiener makes several references to the practical application of vacuum tubes to mimic or replicate systems found within living organisms. For example, on page 130, Wiener discusses modelling the function of a neurone (nerve cell) and states: "it is perfectly possible, for example, to cause any message going into storage to change in a permanent or semi-permanent way the grid bias of one or a number of vacuum tubes, and thus alter the numerical value of the summation of impulses which will make the tube or tubes fire" (Wiener, 1948). Furthermore, electronics engineer and musician Phil Taylor notes: "An entire chapter is devoted to the topic of feedback and oscillation and describes a non-linear oscillator more commonly known as a relaxation oscillator. This type of circuit is used to generate the sawtooth waveform that drives the raster scan in a T.V. set, creating the picture. Relaxation oscillators were constructed from gas – usually neon or argon – filled tubes known as thyratrons. These relaxation oscillator and ring modulator circuits were a few of the building blocks that Louis used to create his unique sounds" (Taylor, 2013). Following the principles and equations described in Wiener's text, Louis constructed many variations of custom oscillators and ring modulator circuits using the valve technology that was ubiquitous to the electrical engineering of the day. His approach was not to think in terms of classical signal processing, but to treat the circuit as a living organism going through a lifecycle – of birth, life, and eventual death (Wierzbicki, 2005). Bebe states: "What we did was to build certain types of simple circuits that had a peculiar sort of nervous system, shall we say. They had characteristics that would keep repeating themselves" (Holmes, 2002).

Analogue valve circuitry is distinct from subsequent transistor or digital sound technologies as it can be overloaded by hundreds of volts beyond its normal operational capacity, thus pushing the circuitry into unknown and inherently unstable states of operation, something that is impossible to achieve with transistors or micro-processors. Of this phenomenon, Louis stated: "in order to create electronic life, you have to be free to abuse the circuit" (Greenwald, 1986). In order to produce the unique tones heard in *Forbidden Planet*, Louis built individual circuits for different themes or motifs. Taylor notes that "this was an innovative approach to composition, where each circuit had its own characteristic *voice*" (Taylor, 2013).

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Fig. 11. An example of Louis Barron's cybernetic circuit diagrams (Taylor, 2013)

The sound circuits often tended to burn out irreparably, which made the process of recording essential in capturing these 'never to be repeated' sounds. Bebe recalls: "No matter what we did, we could never reconstruct them. They just seemed to have a life span of their own… We never could predict the movement of them, the patterns of them. It really wasn't like composing music at all" (Holmes, 2002). The ephemeral noises created by overloading the circuits were edited and compiled by Bebe, who also further manipulated the sounds on tape, using effects such as reverb and tape delay, to produce a rich and dynamic electronic soundscape. Although both had trained in composition, they did not consider this creative process to be composition but rather a cybernetic process; instead of the circuits producing 'notes', they were defined as 'actors', which could be designed to replicate the actions or characters within the film. It was not until they worked with John Cage that they were persuaded by him to consider their soundscapes as music (Chaudron, 2011).

It is also interesting to note that the *Forbidden Planet* soundtrack blurs the distinction between music and sound effects. The Barrons were originally hired to produce sound effects for the film, but the studio was pleasantly surprised with the musicality of the results and asked the Barrons to score the entire soundtrack for the film (Wierzbicki, 2005). In film sound-theory terms (Bordwell and Thompson, 1985), the Barrons' soundtrack blurs the distinction between music and sound effects, between what is diegetic and non-diegetic sound (that which may be heard by the characters within the story world of the film, and that which is not). While, the mise-en-scène of a film is not a 'real' environmental space (it is a fictional one constructed on a film set), the use of film sound in this way displays similarities to Brian Eno's approach to ambient music, in that it is music that is designed to mingle with the surrounding environment and the sounds of each should interact in the audible space, blurring the distinctions between music and environmental sound.[13] This mingling of music and sound effects is very unusual in conventional film sound (more commonly, it tends to be a feature of cartoons); however, it does share traits with the music of other cybernetic music composers such as Eno.

[13] Eno's use of environmental sound in composition is discussed in detail in Chapter 6.2 of this thesis.

When considering this notion of the environment playing a role in cybernetic composition, it is also worth noting that real environmental factors affect analogue circuitry in a way that is not found in digital or transistor technology. Room temperature, humidity, and changes in mains voltage greatly affect the performance of valve circuitry, and just as in conventional musical instruments, this has an important effect on the pitch and timbre of electronic musical instruments that utilise valve technology. While this may be regarded as a minor interaction in the real time compositional process, it does comply with the human/machine/environment paradigm at the centre of cybernetic ontology.

However, it is the way in which the circuits were used in the compositional process that highlights the Barron's cybernetic intentions. Louis was primarily interested in designing audio circuits that had an organic 'built-in uncertainty' and was, by contrast, decidedly unimpressed with the electronic synthesisers that were to follow his inventions. For Louis:

> "[A synthesiser is] designed to do something precisely and repetitively, even if the repetition is just the cycles of a sine wave. It's locked in, it's lobotomised – it doesn't have a chance to express itself. It simply expresses what you want to express, nothing more. But to turn that around, to ask what the circuit wants to express regardless of my intention, now that has authenticity. It's an authentic expression; it produces certain qualities that have feelings to them… synthetic to me is the opposite of organic. Synthetic music lacks this life-like quality. I think that to some extent, I've been able to create circuitry that doesn't have a complete description of what it's going to do. It makes sounds that you can resonate to; it creates emotional rapport… With synthesisers you tell the machine what you want and then hope that it can do it. With me, I don't know what I want – I've given up wanting. I might have an expectation, but I'm process orientated. I care about what goes on, and I accept what comes out. If it sounds good I accept it gratefully" (Greenwald, 1986).

The Barrons saw their audio circuits as models of organic life, which is a distinctly cybernetic viewpoint. It is also interesting to note that when Louis speaks of "emotional rapport", it is not as a response to a composer's intended emotional meaning but in relation to a performative interaction with a technology as it is producing sound. Thus, we see the presence of the performative ontology that is central to cybernetic thinking. Sources such as Holmes, Wierzbicki, Greenwald, and others state that Louis' interest in Wiener's work underpinned not only his approach to building audio electronics, but also the philosophical approach to their working method.

According to scientific historian, Andrew Pickering, one of the central tenets of a cybernetic ontology is a performative image of the world, a 'black box ontology', in which the world is only knowable through our interactions with things in it. "A black box is something that *does something*, that one does something to, and that does something back – a partner in, as I would say, a dance of agency" (Pickering, 2011). In describing the Barrons' compositional process, the necessity of performance and interacting with a black box (in this case the analogue audio circuitry) is central to the Barrons' approach. In conversation with Ted Greenwald, Louis describes prodding the circuit to life by applying a stimulant:

"'It could be a voltage coming in from the outside, or it could be letting more current pass internally by changing a resistance, or by adjusting some kind of feedback.' The method of control is always manual [performed], a variable resistor or capacitor built right into the circuit. Louis doesn't think in terms of filtering, amplifying, oscillating, or any of the component sound-shaping processes that synthesists are familiar with. 'The circuit itself would have a number of those things going on internally to get the total result. If it sounded good to us, we'd try to capture it on tape. From then on we'd have the tape as working material […] these circuits are as if a living thing were crying out, expressing itself. There's an organic type of behaviour going on. […] This life-like quality makes our approach very different from what's called the classical electronic music studio, which uses oscillators, filters, equalizers, and other laboratory instruments. Luening and Ussachevsky were getting started with that at the same time we were. I felt that that was the wrong direction, because laboratory instruments are made to be very precise and very definite, and people aren't. Art isn't. In working with the circuits, you think they'll do one thing, and usually they do something even more interesting that you hadn't expected. […] So I tried to make a circuit, not unpredictable, but with a built-in uncertainty" (Greenwald, 1986).

There are other cybernetic traits evident in the preceding quotations. Firstly, a will on the part of the Barrons to be distinct in their approach to composition, on this aspect Louis noted that: "The musical community absolutely hated the word electronic. Our greatest enthusiasm came from painters, poets, and dancers. Musicians felt that we were betraying the whole cause" (Greenwald, 1986). Furthermore, they also wished to be distinct from other electronic music studios, they did not use the same approach or instrumentation (filters, oscillators, etc.) as other contemporary electronic sound studios. Louis was explicit in that he wished to build circuits with inherent instabilities and then drive them beyond their operating capacity in order to obtain interesting and uncertain results. This approach embraces a performative human/machine/environment paradigm and is distinct from all other forms of composition with electronic music except the cybernetic approach. Secondly, it is clear that within the technological compositional process, the means and the ends have become blurred; the means (the technologies) are no longer simple tools, to be utilised with a fixed goal in mind. Here, the means are driving the process and pointing to new discoveries. This is in keeping with McLuhan's hypothesis of the post-literate society (Coyne, 1995), which also postulates a non-utilisation of text-based scores and an emphasis on performance in the process of making meaning.

It is also worth noting that Louis Barron identified other types of compositional processes that were akin to his own cybernetic approach. In discussing his disdain for enforcing notation-based composition on electronic instruments by adding musical keyboards to synthesisers, Louis stated: "I see more interaction in the way a Theremin works. It made some charming ballet numbers if the proximity of the dancers was controlling the music. That's an example of a looser relationship, an opportunity for the performer to do something different – not just different for the sake of being different, but meaningful – different in a way that makes sense" (Greenwald, 1986). To reinforce this interactive, performative approach, Baron states the limitations of computer-based composition:

> "But a computer is a very rigid thing… The greatest performing musicians almost always take liberties to stretch something, or to tighten it up. They'll play with it; they're not rigidly tied to a metronome. It's actually the attitude with which you engage yourself, and the machine that determines what comes out. There will be people who want to explore, but that exploration can't be conducted with a computer at the moment. I'm interested in things that present computers can't, or don't bother, to do. They're working on machines, which will take their input in natural language, rather than artificial language. We should be able to throw a switch that allows occasional errors – not so much errors as discrepancies" (Greenwald, 1986).

Here we see Louis' frustration at a community of electronic music composers and manufacturers who are, in his opinion, increasingly 'going in the wrong direction' – away from a cybernetic ontology and toward a more traditional reductive approach. Louis' viewpoint chimes with Heidegger's view of technology as an all-consuming, constrictive and reductive force, one, which he believes, conceals true being. Heidegger states that we cannot escape the concealing power of technology; we can only participate in it in a more radical way, one in which we might, if only fleetingly, reveal true being. The Barrons' approach would suggest a recognition of the revealing possibilities of the technology that they utilised, a technology that was designed to create sounds, but was unconstrained by musical convention or notation; a technology that was usurped in unconventional ways in the hope that it might produce or reveal unconsidered insights.

By orthodox standards, even in a modern context, the Barrons' music is unusual; in conventional parlance it is ethereal, mysterious, and otherworldly, but it is also well structured, intriguing, and strangely beguiling. Its originality is a testament to the Barrons' singular cybernetic vision, something which stands as a beacon for all other subsequent work in this field.

5.3 Alvin Lucier

No ideas but in things (William Carlos Williams, 1927).

The work of Alvin Lucier (b. 1931) exemplifies the transition that a number of prominent composers underwent during the second half of the twentieth century: a shift that moved away from a classical, modernist approach to composition, in favour of a process-driven, postmodern, cybernetic approach. The study here traces Lucier's musical progression and examines his impact on cybernetic composition. Lucier's arrival at compositional forms that are essentially cybernetic in nature is largely autodidactic and this is reflected in the somewhat biographical nature of some of the following exposition. Although Lucier would not necessarily recognise himself as a cybernetic composer, it is certain that he knew something of Norbert Wiener and cybernetics (Lucier, 2012). Because of his associations with Edmond Dewan and Gordon Mumma, it is possible that he knew something of the detail of the central tenets of cybernetics, but if that is indeed the case, it is only expressed in the briefest of terms in his writings. However, his work does exhibit a fundamental identification with cybernetic thinking, in particular the recognition that (in the creative act) human, machine and environment form an interlocking and symbiotic, holistic system. As the philosopher of science Andrew Pickering notes, "real-time feedback coupling between performer and performance" and "the decentering of the self into a technological apparatus" (Pickering, 2011) are prominent features of Lucier's compositions. Lucier's work also sees the incorporation of *ends* (goals) into *means* (technologies), where outcomes (of musical works, for example) are not fixed but contingent on the probabilistic processes and complex interactions between these elements. Pieces such as *I Am Sitting in a Room* (1969), *Vespers* (1968), and *Music for Solo Performer* (1965) allow *ends* to be incorporated into *means* by letting the technologies involved in their creation drive process and point toward new discoveries.

Alvin Lucier was born in 1930 in Nashua, New Hampshire, to a musical family. Alvin's parents wanted him to study the piano, but he displayed little interest and instead preferred to obsessively practice the drum kit that was set up in the basement of the family home (Miller-Keller, 2011). This early attachment to rhythm would have an impact on many of his subsequent compositions, such as *Music for Solo Performer* (1965) and *Vespers* (1967), which both utilise percussion instruments, and have strong rhythmic elements. As a teenager, Lucier developed a passion for buying and listening to records, primarily jazz and big band music, but also classical music such as Schoenberg, Beethoven and Brahms: "I knew I was being a little bit snobby climbing a rung above my family's taste, although in no way would I ever knock that taste" (Lucier in Miller-Keller, 2011). Nonetheless, Lucier's personal discovery of this music led to a broadening of his palate and an interest in new musical possibilities.

In 1949 it was decided that he should attend Portsmouth Priory boarding school in order to attain the grades necessary for him to enter university. Lucier describes his education with the Benedictine monks as a formative period. This was a time in which he discovered insights into mathematics, sang Gregorian chant every day, and took heed of an art teacher who would "rant and rave against sentimentality in Art" (Lucier, in Miller-Keller, 2011), certainly something Lucier could not be accused of in his compositions. For him, it was a time of mysticism, scholasticism, ritual, and contemplation, which would have a profound influence on his life and work. Of one incident at the Priory school he recalls "going into the chapel and watching this Trappist monk in the act of contemplation. He wasn't praying the way I remembered pious parish priests prayed. He wasn't pious at all. I got the idea that he was simply thinking. I went back a couple of hours later and he was in the same kneeling position. I thought if there's any such thing as pure thought, this man is doing it. Pure thought would have to be thinking about something specific, without tension or argument. With contemplation one focuses the mind on some thing or idea; with meditation one is supposed to empty the mind. That experience has stayed with me all my life" (Lucier, in Miller-Keller, 2011). This very personal encounter with meditation is intriguing as it chimes with the "perfectly meditative alpha state" (Lucier, 1995) that is central to Lucier's work with bio-feedback, in particular his performance state in his groundbreaking composition *Music for Solo Performer* (1965).

After the Priory school, Lucier gained a place at Yale University, majoring in Music and graduating with a BA in 1954. By now an ardent Stravinskyite, Lucier decided in 1958 to further his studies at the Tanglewood summer school in Boston, studying under Aaron Copland. In the autumn of the same year he commenced his MFA study at Brandeis University, studying with what Copland referred to as the "American Stravinsky School" (Miller-Keller, 2011) of Harold Shapero, Arthur Berger, and Irving Fine. After graduating in 1960, Lucier gained a Fulbright scholarship and spent two years in Rome. During his time in Italy, Lucier attended the now infamous Cage-Tudor concert at Teatro La Fenice in Venice in September 1960. Many in the audience responded to the concert with great anger and it gained a scathing review in *Time* magazine. Stravinsky, who also attended the performance, wryly commented that the riot was not as spectacular as the one that had greeted his *Rite of Spring* (Haskins, 2012). Lucier admits that he was among the audience members who had a violent reaction to the performance: "I even remember yelling something like 'Johnny! Johnny!' from the balcony. I'm embarrassed to think about it now. However, this experience profoundly changed my way of thinking, particularly when I got home. Something about that concert broke through the malaise I was having as a neoclassic composer, knowing there was no future in it. Cage offered a real alternative" (Lucier, in Miller-Keller, 2011).

During his time in Italy, Lucier spent two weeks working at the RAI, Studio di Fonologia in Milan (Lucier, 2012), which was the premier Italian electronic music studio of its day. For several reasons, Lucier's use of this studio was a significant factor in the formulation and style of his subsequent work: Firstly, Luciano Berio and Bruno Maderna, the founders of the studio, were determined that it should not align itself with the *musique concrète* of Pierre Schaeffer's Paris studio, or the *elektronische Musik* being produced by composers such as Karlheinz Stockhausen at the WDR studio in Cologne. With this purpose in mind they equipped the studio with a range of technologies that would not have a particular leaning toward purely tape-based or purely synthesis-based composition (Holmes, 2012). An unusual and influential feature of many notable pieces produced at the Italian studio is that they were speech-based. Another important facet was that a number of significant pieces (and in particular the work achieved in the studio by cybernetic composer Roland Kayn in 1968) were performed in real time – a significant feature of cybernetic composition.

In subsequent years Lucier would use both these traits in the creation of a number of his seminal early electronic works.

It is also notable that Cage produced *Fontana Mix* (1958) in the RAI studio a few years before Lucier's visit. When writing about this piece specifically, Lucier chooses to focus on the composer's choice of relinquishing control to probabilistic processes: "Once the score (determined by chance processes) is fixed you don't alter it. Cage would never throw something out he didn't like on the basis of taste. […] Indeterminacy gets personal preference out of the compositional process. Isn't that a shocking idea? Weren't we always taught that art was about self-expression? What have Cage's pieces got to do with self-expression? Nothing. They've got everything to do with discovery" (Lucier, 2012). It is interesting that Lucier chooses to focus on this aspect of the piece; namely the denial of self-expression in favour of a probabilistic process,[14] the recognition of the fundamental role of probabilistic processes at play in the universe is a key tenet of cybernetics. Here too is the recognition that the composing of the interactions between human, machine and the environment (determined in this case by Cage's chance operation score) is placed at a higher priority than the composer's own personal preference; this decentering of the composer is again a key feature of cybernetic musical composition.

Nothing is known of the work that Lucier produced in this two-week tenure at the RAI studio. It is highly likely that nothing of significance was achieved in this short time period. However, it did provide him with a useful introduction to the electronic studio and the ethos of the RAI studio in particular, which influenced the direction of Lucier's work in subsequent years. It is also worth noting that in 1964, contemporaneous with Lucier's time in Italy, a collective of composer-performers was founded in Rome by Franco Evangelisti: the Gruppo d'Improvvisazione Nuova Consonanza (also known as *The Group*), which contained eminent members such as Aldo Clementi, Ennio Morricone, and the subsequently self-proclaimed cybernetic composer Roland Kayn (Patterson, 2010). It is possible that the formation of this group (the first of its kind in the world) may have had some influence on the founding of the Sonic Arts Union in 1966: a group of American composer-performers that was founded by Alvin Lucier, Robert Ashley, David Behrman, and Gordon Mumma, all of whom were former collaborators of John Cage and David Tudor and who, in contrast to the Italian Group, all utilised electronic means in live performance.

On his return to America, Lucier took up a teaching position at Brandeis University in Massachusetts and in 1965 he invited Cage to perform at the University's Rose Art Museum. This concert saw the premiere of two subsequently iconic works: Cage's *Rozart Mix* and Lucier's *Music For Solo Performer*. It would also mark the beginning of a working relationship and long friendship between the two composers. Initially, Lucier had only thought to invite Cage to perform works of his own, but Cage insisted that Lucier write a work that would also be performed at the concert alongside his own: "At that time (1965) I was not composing music" (Lucier, 2012). After returning from Europe (and following the revelatory Cage/Tudor Concert in Venice), Lucier struggled to find his own unique voice: "my mind was blank, which

[14] As discussed in section 5.2 of this thesis. Cage's intent was not cybernetic. However, Lucier's choice of focus in this instance is.

was good because I could then let ideas come into it unobstructed by previous notions of what music should be" (Lucier, 2012). At this time he had made the acquaintance of Edmond Dewan, a scientist at the local Hanscom Air base, who was researching epileptic fits in helicopter pilots, which he believed were induced by looking into spinning propeller blades or by the fast-moving shadows they cast in the cockpit. Dewan had deduced that this might be due to propeller speeds being sympathetic to alpha brainwave frequencies. In the course of his research Dewan had used a differential amplifier with electrodes attached to the head, to amplify brainwave patterns. Dewan, a keen organist and amateur musician, approached members of the Brandeis music department with the idea that the brainwave amplifier might be utilised in a musical performance of some kind (Miller-Keller, 2011). It is often overlooked in musicological examinations of *Music For Solo Performer* that Dewan was a friend and associate of the founding father of cybernetics, Norbert Wiener, and that without Dewan's cybernetic influence, Lucier's composition would not have come into existence (Kahn, 2013). And thus it was decided that with Dewan's technological assistance, Lucier would utilise the brainwave amplifier to form the basis for his Rose Art piece. In the concert program for the performance Dewan is listed as "Technical Assistant", however after the end of the piece, when the applause had died down, Lucier introduced Dewan to the audience as the composer (Kahn, 2013); in that moment, in Lucier's mind at least, Dewan had played a central role in the instigation of the work.

Music for Solo Performer (1965) was the first musical piece to utilise brainwaves (but certainly not the last). In the performance, electrodes are attached to the back of the performer's head and alpha wave signals are passed via a differential amplifier to a series of normal hi-fi amps. These are then connected to speakers, which are placed against the surface of several percussion instruments, so that the vibration of the speaker cones will in turn resonate the skins (and other surfaces) of the instruments. 8 hi-fi amps and 16 percussion instruments were used in the original performance, including snares, bass drums, timpani, cymbals, gongs, piano strings, a trashcan and a cardboard box (Lucier, 2012). The alpha brainwaves pulse at a frequency of approximately 10Hz. This is not audible to the human ear, but with enough amplification the speaker cones will oscillate forcefully in a regular rhythm (ten times per second), which will in turn vibrate the percussion instruments to which they are connected. Alpha waves only occur when the visual cortex is not stimulated and the body is in a state of rest. So the performer is seated and meditative; the performance begins when the performer closes his/her eyes, and ends when they are opened again. During the performance another operator pans the output of the amplifiers to alternate speakers to vibrate the different instruments.

From the outset Lucier was determined that the composition be a live performance work: "live sounds are much more interesting than taped ones" (Lucier, in Nyman, 1999). The element of theatre was also important to him: "I was touched by the image of the immobile if not paralysed human being who, by merely changing states of visual attention, can activate a large configuration of communication equipment with what appears to be powers from a spiritual realm" (Lucier, in Nyman, 1999).

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Fig. 12. Wiring and routing diagram for Music For Solo Performer (1965) (Lucier, 1995)

Another important aspect of it being a live piece was the inclusion of the environment in the performance ecosystem. Michael Nyman asserts that Lucier "uses the performer himself as an environment, or to be precise the alpha rhythms of his brain" (Nyman, 1999). However, Lucier seems to contradict this notion: "The brainwave piece is as much about resonance as it is about brainwaves. In fact it isn't very much about brainwaves." (Holmes, 2012) Thom Holmes concurs: "It was really about using the room as an acoustic filter, (this was) one of his earliest experiments in this area that has occupied his projects for many years" (Holmes, 2012). However, Nyman also recognises that this performance ecosystem, which entails the performer's performance being affected by the sound that he is emitting, is in essence a "feedback type triggering system" (Nyman, 1999). Andrew Pickering states, perhaps more eloquently, that Lucier's performance system is "a reciprocal and open-ended interplay between the performer and the performance, with each both stimulating and interfering with the other – a kind of reciprocal steersmanship" (Pickering, 2011). The other element to consider here is the use of the electronic equipment; the technology utilised in the piece is not merely a slave to the creative process, not just a means to an end. Instead, it is used to drive the experimental process at work within the piece. The musical outcome is not predetermined; the ends (goal/s) are incorporated into the means (the technology), which drives process and points toward new musical discoveries.

These elements indicate the cybernetic qualities to be found at work in the piece. The qualities of feedback and circularity are central cybernetic tenets and can be found here in the output sound being fed back to the performer to affect his/her mental state, which will in turn affect the output sound. The use of metaphor in design, the mapping of one system (human) onto another (machine), is also an important facet of cybernetic practice; in this case, translating brainwaves into audio waves via a machine interface. Lucier's insistence that the work be performed live (despite the potential technical difficulties) and also the inherent role that the environment plays in the realisation of the piece, demonstrates a recognition and embracing of probabilistic processes at play within such a performance ecosystem, in which temporal interaction with the environment has a large bearing on the resultant sound of the piece. This reflects the concern in cybernetics that all organisms (living or machine) are situated in environments and shaped by them in a circularly causal way. The recognition that the universe operates by probabilistic processes and that these tend toward entropy (or noise) was Norbert Wiener's starting point for cybernetics, which initially concentrated on how order (and ultimately organisms) might arise from this 'noise'. Lucier asserts: "Cage said he was interested in nature's manner of operation, which he thought was random. Cage didn't like my work too much because he said it was too 'cause and effect'. Cage was indeterminate; he would intervene in his compositions with all sorts of randomising processes. I was never interested in that idea. What Cage didn't realise is that systems are naturally chaotic; no interaction is necessary. I want systems to be as neutral as possible because that highlights that the cause and effect are not predictable" (Lucier, in Harder and Rusche, 2013).

Vespers (1968) was a piece that further explored the interaction of human, machine, and environment. Like nearly all of Lucier's work, *Vespers* interrogates acoustic phenomena, in this particular case echolocation. The piece grew from his continuing desire to create original work: "in the late sixties I was looking for something outside of music to inspire me. I didn't want to write the kind of music everyone else did" (Lucier, 2012). The idea for the piece had a long gestation, dating back to his days in Rome. Lucier was working on a composition assignment and during his research he stumbled across Monteverdi's *Vespers* (1610), a work that used echo as a musical theme. It occurred to Lucier that real echoes might be used as a device in composition, echoes that naturally occur in real acoustical spaces (Moore, 1981). In 1967, Lucier was also reading a book entitled *Listening in the Dark* by Donald Griffin, specifically about bats and echolocation; a 'vesper' is also a common type of bat found in North America. Around the same time, he happened to have a chance meeting with a man who worked for a company called Listening Incorporated. The company had developed a handheld device called a 'Sondol' (sonar-dolphin), with the express purpose of rudimentary communication with dolphins. Lucier borrowed a prototype and discovered it to be a good device for describing acoustic spaces via echolocation. After his experience with the Sondol, Lucier had a vivid dream in which astronauts were exploring a dark alien environment with sound guns. The dream was the final catalyst to inspire the making of the piece; he bought four Sondols and waited for an opportunity to realise the work (Lucier, 2012). Again, we see an example of the critical role certain technologies had in the formulation of Lucier's compositions.

In 1968, Robert Ashley and Gordon Mumma invited Lucier to perform at *Once*, an experimental music festival in Ann Arbour, Michigan. Although the piece was to be presented in the large ballroom of the graduate centre of Michigan University, Lucier was unsure as to exactly how the piece would be performed, and had no idea how to proceed until he was in the space with the performers. In the end the piece had to be designed in the dress rehearsal (Holmes, 2012). The work consisted of four blindfolded performers holding Sondols, positioned in four corners of the space. They are told to make their way to a central spot in the space using only echolocation, avoiding each other and objects that had been placed strategically in the space. The performers were instructed to only play when they needed to receive an echo to give them location information. When all the Sondols sounded simultaneously, the noise was cacophonous and the echoes became useless. Natural pauses developed as the performers listened to each other's echoes and waited to play uninterrupted echoes of their own. The performers were also instructed to not speed up or slow down the echo pulses or in fact do anything for musical effect: "It had to be based on survival and task" (Holmes, 2012). This interaction of human, machine, and environment as an integrated system, further reflects themes Lucier explored in *Music for Solo Performer*. It is also noteworthy that goal-oriented behaviour of this type, and the complex interactions it produces, between organisms and in systems, is an often-explored area of cybernetics and also of the fields that grew from cybernetics, such as systems science, complexity science, and artificial intelligence.

Electronic composer Nicolas Collins, a student of Lucier's at Wesleyan University, recalls his involvement in a performance of *Vespers* that took place during his time as an undergraduate:

> "Earlier in the semester, Lucier had introduced Glass's *Music in Parallel Fifths* as a 'return to the year zero' in western music: going back to the first rule of counterpoint, violating it, and seeing what kind of music would evolve along this new branch. In *Vespers,* Lucier reached back even further, to a pre-hominid time before the divarication of music from all other sound, and he invented something that re-connected music to physics, architecture, animal behavior and social interaction – subjects that had intrigued me since childhood, but that I had never directly associated with music. *Vespers* seemed to tell me that I could make music about anything, not just some finite set of concepts handed down by the European classical lineage, that composition was not an activity bound by five lines, but an amorphous glue that could hold together my disparate interests" (Collins, 2010).

Collins expresses several interesting themes here, firstly his joy on encountering *Vespers* and discovering his own return-to-the-year-zero moment that freed him from conventional compositional modes. Secondly, his assertion that *Vespers* evoked a pre-hominid way of understanding sound as music; this theme echoes theories put forward by pragmatic philosophers such as John Dewey, Marshall McLuhan, and Larry Hickman, maintaining that the modern electronic era (the post-literate society) shares many characteristics with the pre-technological, pre-literate society, and not with those of the technological age epitomised by works from the European classical lineage (Coyne, 1995). While McLuhan's theory does not encompass a pre-hominid era it is certainly pointing in a direction sympathetic to Collins' sentiment. Furthermore, Collins' statement also has echoes of a post-human conception that humans are principally not different to other animals (Gray, 2002) and therefore a pre-hominid conception of music is not necessarily all that different from our own, which in turn evokes a non-modern ontology. Finally, Collins' desire, under Lucier's influence, to make his own compositions from disparate interests (including, as he states earlier in the article, electronics, archaeology, linguistics, history of science, art, geology, and music) reflects the multi-disciplinary purview of cybernetics itself.

I Am Sitting in a Room (1969) is the composition Lucier is known for in a wider public sphere (Harder and Rusche, 2013). This is perhaps because in a very clear and distinct way it is the distillation of the essence of his long-term musical project, which is best summed up by his favourite line of poetry; "No ideas but in things" (Williams, 1946–1958); there is no idea or meaning behind the work other than the innate properties of the process and the materials themselves. Lucier has often stated that his main activity in composing is to eliminate the many different possibilities within a piece, leaving only the essential components. It is a minimalist approach, which is very well exemplified by *I Am Sitting In A Room*. The piece is regarded as "one of the 'classical' pieces of the twentieth century and a prototype of process-based music" (Harder and Rusche, 2013). Thom Holmes writes: "This is a work whose reputation often precedes it, and many composers mention it as an influence even if they've only read about it" (Holmes, 2012).

Essentially, the piece explores the resonant sound qualities of a room. A performer reads out a section of text in a room. The speech is recorded and subsequently played back from tape, via a loudspeaker into the room. This new version is then recorded back to tape via the microphone and then played back into the room again, via the loudspeaker, and so on. Over time, the generations of the successive recordings played back into the room produce a degenerative effect on the speech, as more and more of the resonant characteristics of the room can be heard on each recording. In the final generations the speech is barely audible, only the musically resonant frequencies of the room can be heard. The room acts as a filter, reinforcing certain resonant frequencies, while cancelling out others. This process is akin to the visual effect that is gained by making successive photocopies of an image until all aspects of the original picture are obscured (Holmes, 2012). In typical Lucier style, the parameters of the piece (the process, what is to be achieved by it and what you will hear) are succinctly encapsulated within the text-based score:

> "I Am Sitting In A Room" (1969)
> for voice and electromagnetic tape.
>
> Necessary Equipment
> 1 microphone
> 2 tape recorders
> amplifier
> 1 loudspeaker
>
> Choose a room the musical qualities of which you would like to evoke.
> Attach the microphone to the input of tape recorder #1.
> To the output of tape recorder #2 attach the amplifier and loudspeaker.
> Use the following text or a text of any length:
>
> "I am sitting in a room different from the one you are in now.

> I am recording the sound of my speaking voice and I am going to play it back into the room again and again until the resonant frequencies of the room reinforce themselves so that any semblance of my speech, with perhaps the exception of rhythm, is destroyed.
> What you will hear, then, are the natural resonant frequencies of the room articulated by speech.
> I regard this activity not so much as a demonstration of the physical fact, but more as a way to smooth out any irregularities my speech may have.
>
> Record your voice on tape through the microphone attached to tape recorder #1.
> Rewind the tape to its beginning, transfer to tape recorder #2, play it back into the room through the loudspeaker and record a second generation of the original recorded statement through the microphone attached to tape recorder #1.
> Rewind the original second generation to its beginning and splice it onto the end of the original recorded statement on tape recorder #2.
> Play the second generation only back into the room through the loudspeaker and record a third generation of the original recorded statement through the microphone attached to tape recorder #1.
> Continue the process through many generations.
> All the generations spliced together in chronological order make a tape composition the length of which is determined by the length of the original statement and the number of generations recorded.
> Make versions in which one recorded statement is recycled through many rooms.
> Make versions using one or more speakers of different languages in different rooms.
> Make versions in which, for each generation, the microphone is moved to different parts of the room or rooms.
> Make versions that can be performed in real time.
>
> (Lucier and Simon, 1980)

Although the piece is widely regarded as important and influential, it had very humble beginnings. In 1968 Lucier had a casual conversation with Edmond Dewan about a professor at MIT called Bose who had tested the response of the loudspeaker he had designed by recycling sounds into the loudspeaker to see if the response was flat (Lucier, 2012). This gave him the idea that he might be able to realise a musical piece in this way. In early 1969 he borrowed 2 Nagra tape recorders from the Music Department at Wesleyan University where he was teaching, and over the course of an evening he made the piece in the living room of his rented apartment. The work took 16 generations to realise and Lucier stayed up all night playing and recording the speech into the room and splicing the tape together to create a continuous piece. He recalls: "As the process continued more and more resonance of the room came forth; the intelligibility of the speech disappeared. The speech became music. It was magical" (Lucier, 2012). Lucier specifically chose speech as he felt it was "rich in sounds. It has fundamental tones (formants) and lots of noisy stuff – P's, T's, S's, K's" (Lucier, 2012). His choice to use speech is perhaps also recognition of his time at the RAI studio. However, perhaps in a nod to his art teacher at the priory boarding school, he was also insistent that the speech should not contain any poetic or romantic imagery, nothing with high aesthetic value, it should merely describe the process at work within the piece. Lucier recalls seeing the dancer Trisha Brown do exactly this, describing what she was doing as she moved and this also proved to be influential on the compositional form of *I Am Sitting in a Room* (Lucier, 2012).

There is a double function at play in the score's text: the sound of it makes up the piece, but it also describes the score and the process at the same time – a synecdoche in which a part of something refers to the whole of something, or vice-versa. The text appears to 'fold back' on itself in a strange way; the instructions for making the piece are in fact making the piece in real time, there is a sense in which the work is 'making itself'. The elements of looping and feedback are also the main functional mechanisms of the piece. As the process loops from human to machine to environment and back again in an ongoing process, the natural resonances of the room are picked out by the speech. It is interesting to note that the quickest way to find out how the dynamics of a particular microphone, amplifier or speaker system react to room resonances is to simply place them in a room, connect then together and turn up the gain on the amplifier to induce feedback. Here, the frequency of the feedback produced would be dependent on the innate resonance frequencies in the microphone, amplifier, and loudspeaker, the acoustics of the room, the directional pick-up and emission patterns of the microphone and loudspeaker, and the distance between them (Davis and Jones, 1990). All these determinant factors are present in the compositional process of *I Am Sitting In A Room* and the method of making the room resonance audible in the piece is achieved by a kind of 'slow motion feedback', where the room resonances picked out by the speech in each recorded iteration are gradually layered on top of each other to produce a controlled set of feedback tones that are synchronous or sympathetic in rhythm and pitch to the sound being produced by the speaker. Also, the inherent complexity of the (seemingly simple) system means that in one sense the work is ephemeral. No two performances of the piece will sound the same; it has an organic complexity built into the system and probabilistic processes are always at play in the performance.

There are other aspects of the piece that should be considered. In interviews and in writing about the work, Lucier tends to emphasise the acoustic nature of the piece above the technological aspects (Lucier and Simon, 1980), but we should not underestimate the role that the technology played in the making of the piece. Lucier asserts: "I didn't choose to use tape, I had to, because in order to recycle the sounds into space, I had to have them accessible in some form. Tape then, wasn't a medium in which to compose sounds, it was a conveyer, a means to record them and play them back one after the other in chronological order. Without tape I wouldn't have been able to do the piece" (Lucier and Simon 1980). Even here in this admission of the importance of the technology in creating the piece, Lucier is a little disingenuous about the central role that the technology plays in forming the work, seeing it as merely a 'means'. However, the fact that the piece could not be achieved without the technology indicates the central role it had in making the structure and style of the composition. To a degree the equipment directs and drives the process of the piece. Also, the technology and the environment mitigate the outcome of the work to such an extent that in many ways, "the medium becomes the message".

Another element of the piece that should be considered is that despite Lucier's wish to eradicate all sentimentality form the performance, it remains a deeply personal work. Lucier purposefully included this coda to the text: "I regard this activity not so much as a demonstration of the physical fact, but more as a way to smooth out any irregularities my speech may have." As a pronounced stutterer, Lucier was interested in how the process of making the work might smooth out any perceived irregularities. Earlier in the same year, Lucier wrote a companion piece to *I am Sitting in a Room* entitled, *The Only Talking Machine in the World* (1969), which was explicitly concerned with this 'smoothing out' process. The work was specifically designed for people with irregular speech patterns, those with stutters, stammers, lisps, or faulty or halting speech. They were to speak through a PA system with a delay effect added to their voice until anxiety about their voice is relieved or the system fails to produce this effect (Nyman, 1999). Using electronic systems in this way also has obvious analogies with other assistive technologies, such as Wiener's Hearing Glove, and consequently with a cybernetic oeuvre. *I Am Sitting in A Room* was originally designed as a companion piece to *The Only Talking Machine in the World*, but in its realisation it took on greater significance. It is also worth noting how, as the piece progresses and becomes more musical, it seems to attain some characteristics of a Gregorian chant. Lucier focuses our attention to the rhythm of the piece in the text: "*any semblance of my speech, with perhaps the exception of rhythm, is destroyed."* When writing about beat and meter, Lucier muses that in Gregorian chant "the rhythm follows the words" (Lucier, 2012). This meter is also heavily defined by the acoustic space; rooms with long reverb times, such as churches or cathedrals, will require a longer meter, so that the words can be clearly heard. This metaphor of Gregorian chant is not one that Lucier has alluded to in connection to this piece, but it may indicate a subconscious influence from singing Gregorian chant every day as a teenager in the Priory school.

To conclude, Lucier's contribution to the canon of cybernetic music is significant, even though he himself would perhaps shy away from such a distinction, favouring instead to emphasise the role of the composer and the significance of the acoustic phenomena produced by his work. Nonetheless, Lucier was among the first and was certainly the most prominent composer of this early era of electronic composition to fully realise the human/machine/environment paradigm as envisioned in a cybernetic ontology, and this fact has held significance for a number of cybernetic commentators. Douglas Kahn writes of Lucier's chance encounter with Dewan as a prime exemplar of why "it becomes impossible to talk about American experimentalism in any comprehensive way distinct from the knowledge and technologies flowing from the militarised science of the cold war, more specifically cybernetics" (Kahn, 2013). Furthermore, Kahn writes of Dewan's impression of the collaboration with Lucier as being inspired directly by Norbert Wiener's work: "Wiener's influence on [Dewan] and many other scientists was substantive and liberating and, for this reason, Dewan thought that the situation was parallel to John Cage's influence on Alvin Lucier and other musicians. *Music for Solo Performer* can thus be understood as a manifestation of cybernetics, a meeting of Wiener and Cage, one step removed" (Kahn, 2013).

While it could be said that Lucier stumbled into cybernetics rather than pursuing it, his friends certainly noted that while he had a respect for science and technology, he wasn't interested in studying it (Kahn, 2013). It is interesting that the figure he has cited as his predominant artistic influence outside of music is the writer and poet William Carlos Williams (1883–1963). Williams' work is associated with literary modernism, however, it has strong pragmatic and phenomenological leanings, a desire to emphasise the practicalities of life and an interest in things in themselves.

Lucier's two favourite quotations from Williams are: "Don't ask me what I mean, ask me what I've made"; and "No ideas but in things" (Harder and Rusche, 2013) and he often uses these as an explanation of the philosophical underpinning of his work. The intriguing analysis here is how closely these quotations align with Pickering's ideas of cybernetics staging ontological theatre for us; that cybernetic projects can demonstrate an understanding of our being in the world and what is more, that the cybernetic ontology is a performative one; we can only know the world through interaction with it (Pickering, 2011). This is mirrored in Lucier quoting from Williams in order to signify that the work in itself demonstrates its own meaning, that the thing in itself (that particular use of that technology or that acoustic phenomenon in a composition) demonstrates its own idea and in so doing reveals to us something of our state of being in the world. From a musicological standpoint, James Tenney reinforces this idea of revealing: "The sounds that are 'allowed to be themselves' in Lucier's work have always had a mysteriously 'expressive' quality, sometimes I think it is inarticulate nature speaking to us here." (Tenney in Lucier, 1995) This conception is also a Heideggerian 'revealing', where a certain use of technology can lift technology's enframing veil and reveal aspects of true being. Furthermore, the ephemeral nature of Lucier's compositions, the fact that they are performed live and their outcomes are different in each iteration and yet fall within a 'class of goals' indicates the cybernetic imperative that lies at the heart of his work. The emphasis on the composition of interactions over musical notation – Lucier once said of *Music for Solo Performer* that "It isn't a sound idea, it's a control or energy idea" (Kahn, 2013) – also points to a cybernetic compositional mode. These factors are not oblique elements in Lucier's compositions, they are core signifiers and thus his work can be considered as distinct from many forms of electroacoustic composition of this era and thus as part of the cybernetic music canon.

5.4 Herbert Brün

If you want to turn perfectionism into an accusation then you have to use cybernetics. Everything but cybernetics is success orientated. Cybernetics is resource orientated. Cybernetics explains why [something] could happen even though according to you it's totally false. If you don't have such problems, you don't need cybernetics. If everything is the way you want or it is perfect… if perfection is your goal, you don't need cybernetics. If fluctuation control… how one thing flows into another, without having to need causality or violence… transformation, mutation, how does that happen? You need cybernetics (Brün, 1993).

In many ways, Herbert Brün (1918–2000) stands as a contradictory figure in the field of cybernetic music. On the one hand, his work is steeped in cybernetic theory and his connections to some of the leading figures in cybernetics, especially Heinz von Foerster, should mark him as one of the leading lights of cybernetically influenced composition. On the other hand, his compositional work is centred on the sonic capabilities of early computer programming and rarely breaks free of a linear, closed-system approach. The composer Agostino Di Scipio notes that: "Brün's [musical approach] could be seen as thoroughly deterministic, or even hyper-subjective" (Di Scipio, 2002).

Born in Germany in 1918, Brün fled Nazi persecution in 1936 to study piano and composition at the Jerusalem conservatory in Palestine. After the war he continued his musical study at the Tanglewood summer school and at Columbia University, from 1948 to 1950 (www.herbertbrun.org, 2016). As was also later the case with Alvin Lucier, Brün drew early formative influence from his time at Tanglewood, which would culminate in his permanent move to the United States in 1962. Like many of his contemporaries (including Stockhausen, Cage, and Kayn), he toured Europe in the period from 1955 to 1961, making use of the prestigious electronic music studios in Paris, Cologne, and Munich that were "producing some of the earliest examples of non-serial electroacoustic music" (Brün in Feller, 2006).

In 1962, after a lecture tour and series of broadcasts on the function of music in society in the United States, Lejaren Hiller invited Brün to teach at the University of Illinois (herbertbrun.org, 2016). Hiller and Leonard Isaacson composed the first computer-assisted piece of music, the *Illiac Suite* for string quartet, in 1953. This breakthrough established the University of Illinois as a major centre for electronic and computer music. The academic milieu of Illinois was rather unique in that it actively encouraged collaboration between departments and disciplines, including sharing teaching and research projects between subject areas as diverse as electrical engineering, cognitive theory, cybernetics, and music (Feller, 2006).

During Brün's time at the University of Illinois, he established a lifelong friendship with Heinz von Foerster, one of the founding fathers of cybernetics. With the aid of Pentagon funding, Von Foerster established the Biological Computing Laboratory at the University of Illinois in 1958 (Hutchinson, 2004). One of the very few institutionalised cybernetic research centres ever to have existed, it is credited with the development of one of the first parallel computers and the creation of a computerised model of autopoiesis. Eminent cyberneticians such as Ross Ashby and Gordon Pask were among the researchers to work at the laboratory (Hutchinson, 2004). Brün and Von Foerster taught together on a number of courses, including cybernetics, composition, cognition, and social change (Feller, 2006). Brün's immersion in the field of cybernetics, coupled with his access to some of the most advanced computer music compositional systems available – including the MUSICOMP software package for the IBM 7094 (Chadabe, 1997) – led Brün to think about his compositional work in a distinctly cybernetic way.

Von Foerster is credited as being one of the main initiators of second-order cybernetics, which distinguishes itself from the original conception of cybernetics as formulated by Wiener, Ashby, and others as a meta language of command and control, in favour of an evolved conception, more concerned with self-referential systems, the observed system, and autopoiesis. It is interesting to note that while a number of Brün's writings reflect this 'second order' preoccupation (see, in particular, his writings on cybernetics in Brün, 2004), his systemic compositional systems are in many respects distinctly 'first order', reflecting a preoccupation with information theory and the closed system that early computer composition represents. Nonetheless, his compositional theory (be it of the first or second-order variety) is distinctly cybernetic.

Brün's initial forays into computer music composition were exploratory, but took a form already familiar to him, namely the combination of live instrumentation and tape-based soundscape. It involved programmed scores for musicians in conjunction with computer-generated soundscapes recorded to tape, to be played back in synch with each other in live performance. An early example of this approach was *Soniferous Loops* (1964), which utilised the MUSICOMP software and the CSX-1 for audio synthesis (Brün, 2004). On this composition, Brün writes:

> "The structure of the composition, defined by elements and rules together with an algorithm which, in numerous passes (loops), operates in and on the structure as generating function, was translated by the computer into two programs, one for the instrumental sections and one for the tape section" (Brün, 2004).
>
> "The composition and programming of this work represents an attempt at coming to musical terms with two possibilities first offered to the composers by the computer:
>
> 1. Random-flight sequential choices channeled and filtered under control to form-generating restrictive rules; this process created the shape, density functions and parameter details of the instrumental sections.
> 2. The transformation of speed of sound sequences and colour and timbre of sound; this method was used for the production of the tape sections" (Brün, 2004).

It can be seen from Brün's description of the composition that the construction of the piece depends to a large extent on computer-randomised and automated processes, which would in some senses suggest a non-cybernetic approach. However, Brün stated in later interviews that his entire impetus for the composition was to see if it was possible to imbue the composition with human attributes: "My desire was to prove to myself and to Hiller and to other colleagues that I could program a computer with their software so that they would recognise it as a piece by Brün. It was a polemic. The idea was in response to rumors that personality can't get through, that you can't compose with a machine. I wanted to show that that's bullshit" (Chadabe, 1997). Brün's compositional approach to *Soniferous Loops* (1964) can be seen as cybernetic in several senses. Firstly, in seeing the computer as an equal partner in the compositional process, the composer attempts to 'come to terms' with the musical possibilities the computer offers. Rather than the technology being a mere tool, it creates musical structures that the composer would not otherwise have thought of, and there is an inherent respect for the generative nature of this process and its non-hierarchical role in the overall composition. Secondly, the predominant process at work is the composition of interactions that have audible traces rather than creating wanted sounds via interaction with the computer, and although Brün is using a strictly closed system, this attribute chimes with Di Scipio's cybernetic methodology of ecosystemic systems design (Di Scipio, 2003). Finally, Brün's desire for his personality to be audibly evident in the computer composition demonstrates what N. Katherine Hales defines as being one of the most "disturbing" implications of first-order cybernetics, namely the blurring of boundaries between human and machine (Hayles, 1999). Christina Dunbar-Hester notes that this possibility of human personality being made evident though composition mediated by computer was not "an idea that was readily accepted in the world of composition" at the time (Dunbar-Hester, 2010), and perhaps this idea still remains problematic in many respects.[15] Nonetheless, in interview, Brün described the MUSICOMP software as being "extremely intelligent" (Chadabe, 1997). Dunbar-Hester believes that with this statement, Brün was further "invoking a cybernetic ideal" by "indicating a commonality between human and machine 'minds'" (Dunbar-Hester, 2010).

Perhaps one of the most original and cybernetically inspired of Brün's compositional ideas was "anticommunication". Originating in ideas contained within information theory (again displaying a confluence with first-order cybernetics), anticommunication displayed a preoccupation with the inherent meaning, or lack of it, contained in music. Brün drew parallels with information theory as it pertained to language and musical composition. He postulated that just as in theories that relate language to information transfer, where words or bits of information are sequentially expressed, the information or meaning of a message decayed to a state of understanding. The musicologist Ross Feller writes:

> "For Brün, communication speeds the decay of information in a system, whereas anticommunication retards or delays the decay because of its required use of systems or mechanisms not yet available. Restated within a semiotic frame – communication encourages the objects of signs to couple, while anticommunication attempts to discourage this coupling, if only for a brief amount of time. The gap opened by this delay contains, for Brün, possibilities for non-trivial, non-status quo connections to occur, alternatives to the convenience of recognition" (Feller, 2006).

For Brün this meant the disrupting of recognised musical chords or motifs so that their recognised 'meaning', at least in the sense of the Western art tradition (major, minor, happy, sad, triumphal, melancholic, etc.), would not be immediately apparent, such that a "free-floating signification potential" (Feller, 2006) might be

[15] However, a distinction must be made here between a composer imbuing a work with meaning and a musical work being recognisable as being written by a certain composer.

realised.

For Brün, anticommunication should not be confused with a lack of communication or non-communication (where no communication was intended). Instead it was an attempt to supplant obvious meaning with more open possibilities: “Anticommunication is an attempt at saying something, not a refusal to say it. Communication is achievable by learning from language how to say something. Anticommunication is an attempt at respectfully teaching language to say it” (Brün, 2004). In musical terms this may be seen as a rejection of non-deterministic, aleatoric or chance procedures – such as Cage’s *Music of Changes* (1951), or Stockhausen’s *Klavierstück XI* (1956) – in favour of a new kind of determinism that utilises methods such as placing familiar sounds or musical phrases in a “new contextual environment”, or by using “gesture inhibiting materials” (Brün, 2004). Anticommunication is an attempt to impose a system of disruption based on a philosophical viewpoint, a way of usurping traditional musical meanings and the imposition of traditional compositional structures such as textural notation. In cybernetic terms this would imply that the composition be mediated by technology, an approach that Brün is renowned for. If one further implies that language and modes of communication are technologies, then anticommunication may be subject to a Heideggerian analysis in which technologies conceal true being, and anticommunication can be seen as an attempt to subvert those technologies and hopefully reveal true being.

One of the most prevalent examples of anticommunication in practice is Brün's 1964 piece, *Futility. A*lthough written in the same year as *Soniferous Loops, Futility* has a very different musical form, one that is much less musically conventional (for example, it contains no live instrumentation), and interestingly, contains a number of features that are reminiscent of the work of other cybernetic composers such as Roland Kayn, Alvin Lucier, and the Barrons. In particular, these include the placing of speech as a central component and its juxtaposition with a soundscape of synthesised and acousmatic sounds that express an extreme variety in frequency, content, and dynamics, from loud and noise-like, to ethereal and dreamlike. The piece takes a strict antiphonal form, oscillating back and forth between several seconds of computer-generated sound interjected with several seconds of spoken-word material. This can be jarring and has a somewhat disorientating effect, where you don't quite know what to expect from one moment to the next, whether it be the extreme sonic differences in the electronically generated soundscape, or the disparate words spoken by the narrator. This jarring effect is Brün's attempt at putting anticommunication into practice in a compositional context; to deliberately usurp expectations, thus delaying the decay of information into a recognised meaning and creating the potential for “free-floating signification” (Feller, 2006). The text, written by Brün, specifically refers to the decay of information. Academic and dispassionate in tone and content, it has the air of an information-theory text. The delivery, by a female narrator, is monotone and robot-like. The narrow bandwidth filter placed upon the voice further emphasises the machine-like tone. Both these tropes signal the cybernetic imperative that underpins this work (both in a theoretical sense and from a popular culture perspective; imagine cyberman as composer!).

It is also important to note that anticommunication is not only a compositional stance, but also a mode of listening. The knowing involvement of the audience in the meaning-making process chimes with ideas expressed in artist Roy Ascott's cybernetic art manifesto *The Construction of Change*[16] (Ascott, 1964) in which "the participant becomes responsible for the extension of the artwork's meaning" (Ascott, 1964). Although it is unclear if Brün had ever read Ascott, the idea of the audience's perception having a large bearing on the outcome of an artwork's meaning was certainly in the general milieu of the times. Both Di Scipio (2002) and Feller (2006) cite Theodore Adorno's constructivist theories as being a major influence on Brün's thinking and compositional approach, which lends further credence to a constructivist/cybernetic ontology underpinning anticommunication. Di Scipio also equates Brün's approach, particularly in his *Sawdust* project (a series of computer compositions from the period of 1976–1981), as being akin to Xenakis' cybernetic methodology: "Xenakis defined his 'mechanism' as a minimal set of rules capable of allowing the emergence of musical flow of particular properties. This approach was shared by Brün, whose Sawdust program actually included a very limited set of machine instructions" (Di Scipio, 2002). However, while Di Scipio cites Brün's work as a formative influence on his own, he also believes that the theoretical compositional approaches of both Xenakis and Brün display a kind of "ecological inadequacy" (Di Scipio, 2002), in that "they tended toward self-organising systems, but only to the extent that they resulted in homeostasis, namely a progressive reduction of information, a compulsory path towards a definite, although unforeseen end" (Di Scipio, 2002). Di Scipio's focus on homeostasis (rather than autopoiesis) frames Brün's work as having distinctly first-order cybernetic attributes.

By his own admission, Brün saw his musical work, particularly after 1962, as a cybernetic project. Despite Di Scipio's view that Brün's work was limited in its cybernetic purview, it still remains a valid and important contribution to the field and to computer music more generally. Brün remained a committed cyberneticist, he received the Norbert Wiener medal from the American Society for Cybernetics in 1993 and he remained dedicated to utilising cybernetics in his work, writings, and public lectures until his death in 2000. Brün's composition *Infraudibles* (1967) was included in the seminal *Cybernetic Serendipity* exhibition at the ICA in London in 1968[17], and thus he may be viewed as one of the leading public exponents of cybernetic music. His work and ideas are still pertinent today, and his influence on Agostino Di Scipio, in particular, signals the resilience and relevance of his music and ideas.

16 Explored in more detail in chapter 6.2, of this thesis.

17 Cybernetic Serendipity was a genre-defining exhibition in terms of public awareness of the use of cybernetics in art. This exhibition is discussed in greater detail in relation to Gordon Pask's work in Chapter 6.1 of this thesis

5.5 Roland Kayn

Music is sound - and sound is self-sufficient (Roland Kayn in Ricci, 2005).

A number of composers who have utilised cybernetic methods in their compositions have been ostracised from the general musical and scientific communities, either because their compositions have not been considered as music (as was the case with Louis and Bebe Barron (Wierzbicki, 2005), or because their work as cyberneticians was not considered scientifically rigorous enough – as was seen in a general concern about the 'pollution' of cybernetics due to popular exposure, voiced by Warren McCullock, Julian Bigelow, and Heinz von Foerster, among others (Dunbar-Hester 2009). Roland Kayn (1933–2011) is one such composer who released a significant body of electro-acoustic work drawing on themes and methods derived from cybernetics and information theory, yet he was ostracised from the ranks of the Darmstadt composers and did not gain significant public recognition in his lifetime outside of Germany and Holland.

Kayn was born in 1933 in Reutlingen, Germany. As an undergraduate student in the period from 1952 to 1956, he studied composition and organ in Stuttgart and at the church music school in Esslingen. Between 1956 and 1958, he studied scientific theory as a master's student at the Technische Hochschule in Berlin with the philosopher Max Bense. He also simultaneously studied at the Musikhochschule with Boris Blacher (composition) and Josef Rufer (analysis). While there he also attended seminars by Fritz Winckel and Oskar Sala (Kayn, 1977a).

Max Bense, in particular, appears to have exerted a strong influence on the young Kayn (Patterson, 2009). Bense's lifelong project was an attempt to remove the separation between the humanities and the natural sciences to integrate philosophy with mathematics, semiotics, and aesthetics in a combined perspective that he termed *existential rationalism.* Bense's work with mathematics in art and language led him to be interested in the then nascent fields of information theory and cybernetics. Bense read Norbert Wiener's *Cybernetics or control and communication in the animal and the machine* (Wiener, 1948) in 1949, just one year after its publication and twelve years before the German translation (Walther, 1999). Indeed, in July 1955, Bense invited Wiener to speak at the Technical University of Stuttgart and in addition, Bense wrote prefaces to a number of prominent books on cybernetics by European authors, such as Louis Couffignal's *Thinking Machines* (*Les Machines à Penser*, 1952) and *Cybernetic Basic Concepts* (Les Notions de Base, 1958), and Gotthard Günther's *The Consciousness of the Machines, A Metaphysics of Cybernetics* (1973). Bense also instigated a series of articles entitled "Cybernetics and information" which were published by Agis Verlag in Baden-Baden in l960 (Walther, 1999; www.wikipedia.co.uk, 2013).

Although Kayn did not fully realise his first piece of cybernetic music until 1966, Bense's integration of mathematics and art can be seen as an important influence on Kayn's composition post-1958. In the following years, his music saw a gradual move away from traditional instrumentation and musical structure, culminating in a complete departure from traditional composition and a full embracing of cybernetic principals and process (Kayn, 1977b).

Kayn's musical tutors, Boris Blacher and Josef Rufer were both strong proponents of modernism, and as such, perhaps cannot be seen as being influential on Kayn's cybernetic approach, particularly the musicologist Rufer, who was Schoenberg's chief assistant between 1925 and 1933 and a vital witness and documenter of the development of the 12-tone technique and serialism (Stuckenschmidt, 1977). However, Blacher studied mathematics and architecture as an undergraduate before studying music and exhibited some of these influences in his application of mathematical techniques to create 'variable metrics', as in works such as *Piano concerto no.2* (1952). He also understood what it was to be ostracised as a composer, as his music was declared 'degenerate' by the Nazi regime, forcing him into internal exile during the war (Boosey and Hawkes, 2013). So there is a greater claim to be made for a formative influence emanating from Blacher, if only, perhaps, in ways that tended to be non-musical.

Although the influence of serialism is evident in Kayn's works as a student, he refutes this, citing "ideological differences" with the tenets of 12-tone composition (Kayn, 1977b). Perhaps of greater import to Kayn's later work with technology and compositional progression is the academic influence of Fritz Winckel and Oskar Sala. Along with Boris Blacher, Winckel founded the Working Group for Electronic Music, which culminated in 1953 with the instigation of the electronic music studio of the Technical University in Berlin (Wikipedia.de, 2013). He was also an electronic instrument builder and had a particular interest in synthesising speech. Oskar Sala, like Kayn, studied piano and organ as an undergraduate, but developed an interest in early electronic instruments, in particular the Trautonium. Sala further developed the design of the Trautonium, which he later used to score a number of notable film soundtracks, including films by Fritz Lang and Albert Hitchcock's *The Birds* (Holmes, 2012) A reconfiguration of the Trautonium (the monochord) was also used in the NWDR studios in Cologne and its tone generators may be heard in many pioneering German electroacoustic works produced in this studio in the 1950s and early 1960s. This exposure to the principles of the electronic music studio and early sound synthesis provided Kayn with insights he would later utilise in his technological compositions.

According to Kayn, his first contact with electronic music came when he was studying as an undergraduate in 1954. He became acquainted with Herbert Eimert, the then director of the NWDR music studio. Eimert granted Kayn use of the studio for a limited period, which unfortunately proved to be "relatively unsuccessful" (Kayn, 1977b). However, as a student and for a number of years after his graduation, Kayn gained some reputation as a traditional composer. Composing works for piano, organ, and orchestra, he was awarded the prize for the best foreign work at the Music of the 20th Century festival in Kairuzawa, Tokyo. In 1960, he was awarded the Prix de Rome (Villa Massimo) and in 1965 the music prize of the Biennale des Jeunes Artistes in Paris. The Italian contingent of the International Society for New Music also awarded Kayn with 2 prizes for *Vectors 1* and *Schwingungen*, his orchestral works from 1964 (Ricci, 2005).

However, despite these early successes, Kayn struggled to gain recognition in his own country as a traditional composer. Kayn cites the performance of his 1958 work *Aggregate* as making him "persona non-grata on the concert stage" (Kayn, 2013b). Without qualification, this is an unusual statement: how can one performance of a work lead to a composer being ostracised from the concert stage? One explanation may lie in the fact that the only recorded version of this work is a live recording taken from the 1959 Darmstadt International Summer School. While little is known of the style of the piece, the instrumentation was for brass, strings, and striking mechanism for five Players (Kayn, 2013a). The Darmstadt summer school was perhaps the most important and influential meeting point for composers of new music in the twentieth century. Formed by the music critic Wolfgang Steinecke (1910–61) and the composer Wolfgang Fortner (1907–87), initially with the permission and then later with the active financial backing of the United States military government, its initial purpose had been to promote new music that had been suppressed under the Nazi regime. Pierre Boulez, Bruno Maderna, Karlheinz Stockhausen, Luciano Berio, Earle Brown, John Cage, Aldo Clementi, Franco Donatoni, Niccolò Castiglioni, Franco Evangelisti, Karel Goeyvaerts, Mauricio Kagel, Gottfried Michael Koenig, Giacomo Manzoni, and Henri Pousseur were regular attendees of the summer school between 1951 and 1961 (Wikipedia, 2013b). Following Schoenberg's influence, the summer school was in the sway of the progressions of the 12-tone technique, namely serialism. However inspiring and progressive the summer school in this period may have been, it was not without its critics. Composers such as Hans Werner Henze reacted against the principles of the Darmstadt School, particularly the way in which composers were forced to adopt the tenets of serialism or be "ridiculed or ignored". In his writings, Henze recalls student composers rewriting their works on the train to Darmstadt in order to conform to Boulez's expectations (Henze, 1982). Franco Evangelisti, who was one of the leading figures of the Darmstadt School, was also critical of the dogmatic "orthodoxy" of certain zealot disciples, labelling them the "Dodecaphonic police" (Fox, 2006). In his writings, the composer Konrad Boehmer also stated that the "concert programme […] featured seriality as the dominant doctrine of the early fifties". Perhaps in this context, Kayn's compositions, which favoured "mathematical editing procedures" (Kayn, 1977b) rather than strict serialist techniques were ridiculed or ignored by the Darmstadt inner circle. If this were the case it would certainly explain Kayn's assertion that he was made "persona non-grata" after the performance of his composition *Aggregate (1958)*.

Whatever the cause, after 1959, Kayn switched his attention away from composing for traditional instruments toward an approach that treated the electronic music studio as a means of composition. Between 1959 and 1963, he worked as a freelancer at various electronic music studios around Europe, including Warsaw, Cologne, Munich, Milan, and Brussels. While at the experimental studio of the Polish Radio in Warsaw in 1959, he began work on a draft version of an electronic composition *Impulse,* for seven 2-channel tape sources. Although the score was submitted, the full realisation of the piece proved impossible due to technical limitations in the Polish studios (Kayn, 1977b). Kayn tried again to realise the piece at the WDR studios in Cologne in 1961, and once more in 1962, at the Siemens studio in Munich. However, "even the punched tape technique employed in Munich proved incapable of bringing the project to completion in a reasonable period of time" (Kayn, 1977b). These frustrations in realising his piece within the confines of the electronic studio led Kayn to seek other forms of electronic composition.

Perhaps what Kayn realised was that even if this project were achieved, it would not be able to fulfil his burgeoning cybernetic vision – and nor would any other project created in this way.

Fig. 13. Score for Allotropie, 1964 (Kayn, 1981)

B 31 Kayn: Galaxis, Ausschnitt: 90° des Kreises
Hermann Moeck Verlag, Celle

Fig. 14. Excerpt from the score for Galaxis (Kayn, 1962)

In 1962, Kayn began to write compositions that had a "biocybernetic" structure, which he described as "music written for ensembles and non-electronic instruments that adhered to cybernetic rules and processes" (Kayn, 1977b). Pieces such as *Galaxis* (1962), *Inerziali* (1963), and *Allotropie* (1962–64) conform to this format. Another major departure for Kayn was his introduction to – and participation in – improvised music. In 1964 he joined the Gruppo d'Improvvisazione Nuova Consonanza (also known as "The Group"), a collective of composer-performers founded by Franco Evangelisti in Rome, it also contained other eminent members such as Aldo Clementi and Ennio Morricone (Patterson, 2010). The Group, in which Kayn primarily played organ, is acknowledged to be the first experimental composers' collective of its kind. "The ensemble functioned as a laboratory of sorts, working with anti-musical systems and noise techniques in an attempt to redefine the new music ensemble and explore 'New Consonance.'" (Harrison, 1999). Kayn cites this experience as a "crucial detour into improvisation", which "helped him find his definitive musical direction" (Kayn, 2013b).

The feedback loops associated with cybernetics find a strong resonance with improvisatory practice, and are acknowledged by free improvisers such as Evan Parker as being one of the models that an improviser may draw upon (Toop, 2004). It is possibly no coincidence that the LP released by The Group immediately after Kayn's departure in 1968 was entitled *Feed-Back* (RCA records). However, it is also perhaps not so much the influence of feedback loops that had an effect on Kayn's future work, but rather that his time with The Group demonstrated that the process of composition might be achieved in other ways: to "set up some initial parameters and ride the dynamics of the system in the direction you wish to go", as Brian Eno has proposed as a cybernetic strategy, quoting the cybernetician Stafford Beer (Whittaker, 2003).

This 'freeing up' of compositional structure coupled with Kayn's discovery of modular synthesis saw another shift in his musical direction. Between 1966 and 1968, Kayn worked on his first fully realised electroacoustic work, *Cybernetics I.* Writings on Kayn's work are sparse, but his large catalogue of recorded works and their accompanying sleevenotes stand as a testament to his approach and methodology. Work on *Cybernetics I* was conducted at the Studio di Fonologia, RAI in Milan (Kayn, 1977b). There are three reasons why this studio in particular was instrumental in the development of this work: Firstly, the RAI studio was one of the best equipped in Europe at that time. Secondly (as previously stated in section 4.3 in relation to Alvin Lucier's involvement with the RAI studio), the artistic directors of the studio, Luciano Berio (1925–2003) and Bruno Maderna (1920–1973) were determined that the Italian studio should not align itself with either the musique concrète being produced by the GRM Paris studio, or the rigidly rules-based, serialist compositions being produced at WDR in Cologne. Thirdly, one of the hallmarks of the Milan studio was the use of speech as sound material (Holmes, 2002). Kayn drew influence from each of these attributes in the composition of *Cybernetics I* in which the sound sources were all of "vocal origin, including animal noises" (Kayn, 1977b). These were then fed from tape through a series of audio-processing devices, which Kayn asserts "act according to the principle of self-organisation" (Kayn, 1977b), to produce 10 separate sound sources, which were mixed in real time and recorded to tape (Kayn, 1977b). It is not clear what audio processing took place but the Milan studio was well equipped to modulate the sound in a multitude of ways, via LFO, reverb, numerous filters, ring modulators, a time regulator, and an amplitude filter (Holmes, 2002).

One of the main cybernetic elements of the composition (and what distinguishes it from the Cologne and Paris schools) is that it was accomplished in real time. As an organist, Kayn was well versed in manipulating controls to change the resulting timbre in the performance of a piece and this skill was put to good use in the compositional process of *Cybernetics 1*. "The electro acoustic project *Cybernetics* developed from the idea of determining, by means of random repertoire of acoustic signals, the course of the composition in real time i.e. while a multiplicity of complexly interdependent regulatory procedures are working together. In this connection, a further aspect was the removal of the theoretical contrast between technical and organic systems by means of the application of cybernetic controls to both areas" (Kayn, 1977b). Here we can see Kayn's biocybernetic imperative in equating the systematic processes applied prior to the recording (the routing of the modulation matrix and the order of the initial sound signals from tape) with the systematic, human control processes he is utilising as the real time operator of the compositional system. He talks of the mixing console as "simulating a heuristic situation" (Kayn, 1977b); heuristics are often employed in cybernetic systems (as opposed to algorithms), meaning that a goal can be sought by trial and error, the outcome of which may not be optimal but will be successful within a margin of error (Beer, 1994). Heuristics cut out the need for specifying every operational possibility, thus potentially saving computational time and energy. On controlling the system as the composition unfolded, Kayn wrote that the "density of the information (the mix of sound sources) corresponded to particular parameters of state (entropy values)" (Kayn, 1977b), meaning that if too little was happening in the soundscape, more sound sources and modulations could be added (in real time) and vice versa.

Fig. 15. A "sign store" and "control system" score for Kayn's Cybernetics 1, 1968 (Kayn, 1977b)

Kayn also discusses the aesthetic qualities inherent to the cybernetic composition, "the fact that the process of creation is integrated into the acoustic super-signal, and remains transparent. […] The listener is thus able to follow the compositional process as it develops; the acoustic construct is hence made more lucid and more of a total auditory experience for the listener" (Kayn, 1977b). He also hopes that "the reality of what 'exists' on a purely 'technological' level will surely prove fruitful in terms of aesthetic innovation" (Kayn, 1977b). Kayn's concern with the aesthetic qualities of the piece coupled with the technological and mathematical construction demonstrate the influence of Max Bense's work. Kayn also shows this influence when he writes the following in explanation of the piece: "For a number of years now it has been possible to observe that such apparently diverse areas as sociology, aesthetics and medicine have been characterised increasingly by the incorporation of mathematical processes and methods [and] since 1957, of the digital computer as an aid to the realisation of instrumental and electronic compositions" (Kayn, 1977b). However, he goes on to make a distinction between, on the one hand, electronic music that is pre-programmed into a computer, which forces the composer to think in "mechanical terms" and thus create works that tend to be of "a repetitive nature", and on the other, cybernetic composition, which has a "critical degree of indeterminacy, which allows a more effective approximation to organic reality" (Kayn, 1977b). He also equates the "open system" employed within experimental compositions, containing the "usual instrumental ensembles", with cybernetic composition, stating: "synthetic sound processes which are generated by means of open systems do not have additive components as their basis, but are derived from functions within non-linear programmes" whose "specific character lies in the fact that they do not remain stable, but rather proceed in sudden jumps" (Kayn, 1977b), meaning that the electronic compositional system he has derived allows for more unpredictability and variety than conventional experimental strategies.

Kayn made two further pieces at the RAI studio in Milan with 'cybernetics' in the title: *Cybernetics II* (1968), an ambitious piece, which included live vocal performances (7 choir groups, a tone generator, sound sources, live electronics and tape), and *Cybernetics III* (1969), which was a refinement and expansion of his first electroacoustic cybernetic piece. In 1970 Kayn moved from Italy to Holland to take up the position of Programme Officer at the Goethe Institute, Amsterdam. During this time he was invited to use the sound studios of the Instituut voor Sonology Rijksuniversiteit (Institute of Sonology at Utrecht University), which became his compositional base until 1991 (Kayn, 2013b). The move proved to be creatively fruitful, with the university studios in Utrecht providing the equipment for him to fully realise his cybernetic compositions. The commentator on experimental and electronic music, Thomas Patteson writes:

> "The composer Gottfried Michael Koenig, director of the studio since 1964, had recently overseen the installation of a state-of-the-art analogue system of independent modular units, such as oscillators, filters, envelope generators, and logic circuits. At the centre of this configuration was a 'variable function generator', essentially a primitive sequencer that could be programmed to store a series of voltages, which were then used to control the various components of the studio. With this system, Kayn was able for the first time to realise his idea of cybernetic music, which involved elaborate configurations of connections and feedback loops that create complex and unpredictable sonic interactions. Kayn 'composes' the initial setup of the studio components, but once the sound is set in motion, it is allowed to take its own course. In this way, Kayn believes, 'the electronic system develops a sort of capacity to think for itself, a capacity which in a sense can be described as artificial intelligence… Existential Being, as it were, takes the place of a logically functioning consciousness'" (Patteson, 2010).

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Fig. 16. A cybernetic music synthesis patch designed by Kayn at the Studio de Recherches et de Structurations Electroniques, Brussels (Kayn, 1977a)

It was in Kayn's interaction with the equipment in the Utrecht studio that his biocybernetic vision became realised in the way he had first envisioned. The capacity of the modern synthesizer modules and the complexity of the patching matrix allowed for the construction of self-sustaining musical systems, which, once fed with initial sound sources, could, with little interference, produce almost indefinite soundscapes of great variety and musical scope. The 3-LP and 4-LP box sets he produced at this time attest to the prolific output this compositional system could generate. The music critic Frans van Rossum describes Kayn's working method in this era:

> "His electronic pieces start with defining a network of electronic equipment. The nature of the network, and its inherent potential, play a large role in determining the final audible result. Next, the composer collates the basic information about this network and develops a system of signals or commands that it can obey and execute. These have to be incorporated in a system of controllers, adjustments and operations which can realise the composition. This demanding work may take years of construction and tests, and when the system is activated, the resulting composition is recorded to tape once only from the beginning to the end" (van Rossum, 2011).

Kayn's works *Infra* (1979–80) and *Tektra* (1980) are perhaps the artistic zenith of this period. *Infra* was produced using orchestral sound sources and *Tektra* with electronic sources (van Rossum, 2011). *Tektra*, in particular, achieves a very audibly organic aesthetic, with musical structures seeming to exist only in reference to their own ecological rules; soundscapes that constantly evolve, while always seeming to maintain an internal, self-referential consistency. This is perhaps no coincidence as the production of electronically synthesised sound sources could also be tied into the electronic compositional matrix (via a patch bay of physical inputs and outputs), rather than merely providing the initial sound energy, as would be the case with a source from tape. In this type of coupling, control sources could be used to directly affect waveform production and vice versa, thus making it possible to form what Von Foerster called a *recursive coupling* (Von Foerster, 1960): a feedback loop that enables a balance of control between elements in a system, wherein a change in one element affects all the others, including (recursively) the initial change state component. This type of system is also synonymous with living systems (Von Foerster, 1960). While it is not known to what extent Kayn achieved recursive coupling in his compositional structure, it is technologically concurrent with the equipment he had available and the sonic aesthetic would seem to suggest that this had been achieved to some extent.

Fig. 17. Synthesizer patch and performance set up of Simultan, van Gogh Museum 1976 (Kayn, 2013b)

Before concluding this examination of Kayn's cybernetic compositional methodology, it is worth making two further points. Firstly, Kayn not only abandoned traditional (or more often any) notation in his cybernetic works, he also gave up on ideas of conventional musical structures having any bearing on his composition, instead favouring evaluation in cybernetic terms. As van Rossum notes: "Concepts like melody, harmony and rhythm, atonality or serialism do not apply to Kayn's music, which is more like a continually changing resonating structure. More than that, the composer presents his music as an artifice which he constructs and sets in motion, but once he has done this, it is left to move through space, without outside interference, according to its own internal laws" (van Rossum, 2011). Secondly, as we can infer from this comment, Kayn wished to understate the role of the composer in cybernetic music, perhaps the only possible position when rigorously advocating self-organising works of music. The music critic Massimo Ricci further elucidates: "The concept according to which every musical piece should be defined in every single detail by its author is firmly contrasted by Roland, who insists that cybernetic music is self-regulated, leaving behind both the narrative element and the psycho/emotional minutiae usually associated with the idea of the 'author' and with 'art'. This means that not even the ideator of this framework can predict the definitive outcome, since the sonic processes do not have a real epicenter, but instead, every sound bears the very same weight and importance in comparison to the others. 'Music is sound – and sound is self-sufficient', declares Kayn." (Ricci, 2005) It is worth noting that this statement from Kayn is extremely similar to an assertion from the cybernetic composer Agostino Di Scipio, in which he declared: "sound is the interface" (Di Scipio, 2003). However, they have slightly different intended meanings. In Di Scipio's case this declaration relates to all functions in a recursively coupled compositional system taking place in the audible domain, and alternatively, in Kayn's case, his statement pertains to the non-necessity of representational systems, such as notation, in composition. Nonetheless, they both assert the primacy of *sound* in the compositional process and this is perhaps testament to the common cybernetic ontology shared by both composers. There are also some striking similarities in the two composers' methodologies, in particular, Di Scipio's emphasis on composing interactions as opposed to interactive composition[18] (Di Scipio, 2003). This is mirrored in Kayn's meticulous and complex patch preparation, so that a performance may be realised when open systems[19] interact by means of "a complex network of interlocking regulatory and operative procedures" (Kayn, 1977b), which can in turn create a self-sustaining system. These ideas are strikingly similar, which is unusual considering the composers' major cybernetic compositions are almost thirty years apart, but they do strongly indicate a common cybernetic ontology underpinning both their methodologies.

To conclude, perhaps we should turn our attention once again to ontology. Kayn's work is undoubtedly aligned with the non-modern ontology of cybernetics. However, another interesting facet here is the composer's own stated preoccupation with being, particularly as it pertains to modes of listening to cybernetic music:

> "Existential being, as it were, takes the place of a logically functioning consciousness. The characteristic impression made on the listener by sound events which arise in this way [i.e. cybernetically composed] seems to be one of simultaneity or dependencies between control structures and programme structures – that is, the fact that the process of creation is integrated into the acoustic supersignal, and remains transparent. The control structure lies within the range of audibility, thereby forming an integral component of the generating process. The listener is thus able to follow the compositional process as it develops; the acoustic construct is hence made more lucid and more of a total auditory experience for the listener – the acoustic sphere is, so to speak, 'socialised'" (Kayn, 1977b).

Here Kayn wishes to emphasise that the listener is made aware of how the piece is compositionally constructed and that this is realised by technological means. This is undoubtedly Heideggerian 'revealing' in the sense that Kayn wishes to emphasise existential *being* taking precedence over logical consciousness in the listening act and that it is a technological process that is allowing this to happen. In Heideggerian terms, this particular subversive use of the technology is lifting technology's inherent enframing veil so that we may glimpse, if only fleetingly, a facet of the nature of true being (Heidegger, 1954).

It is also of note that Kayn wished to stand apart from other compositional modes. He coined the term 'cybernetic music' in the late 1960s (Kayne, 1977b) in order to be radical and propose a new form of compositional practice that stood outside of conventional electroacoustic and modern classical norms. While it is fair to say this idea did not become established in the public imagination or in experimental music circles, it did pave the way for a consideration that cybernetic music could be a viable compositional mode, with its own rubrics and aesthetic concerns.

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[18] A detailed explanation of this compositional standpoint is to be found in chapter 6.3 of this thesis.

[19] By 'open systems', Kayn is referring to other unpredictable systems such as humans, performing live, or interfering with control data in real time, environmental sound, and unpredictable combinations of other sound sources such as tape.

Chapter 6

Second Order Cybernetic Music

6.1 Gordon Pask and the Musicolour Machine

"Cybernetics is the art of manipulating defensible metaphors"
(Gordon Pask in Von Glasersfeld, 1992).

Gordon Pask (1928–1996) is one of the few cyberneticians to engage directly with musical practice. Pask was not, however, a composer. The majority of his work centred on inventing adaptive learning machines – interactive technological devices that were designed to aid in the process of learning. One such device of particular interest to this thesis was the Musicolour Machine, which was designed to enhance musical creativity, as well as acting as a new form of interactive entertainment.

Pask was an eminent academic, who obtained three PhDs. He was a Visiting Professor and also taught at many academic institutions, including Brunel University, University of Chicago, the University of Illinois Urbana-Champaign, Concordia University, Georgia Institute of Technology, The Open University, University of New Mexico, Architectural Association School of Architecture, and MIT. However, his pre-eminent vocational preoccupation was with his own commercial research company, Systems Research (Glanville and Scott, 2001). Like many cyberneticians, Pask's academic study was eclectic, encompassing the study of mining engineering (Liverpool Polytechnic, graduating 1949), physiology (Downing College, Cambridge, graduating 1953), and psychology (University College London, graduating 1974) (Glanville and Scott, 2001). It was while at Cambridge that Pask was introduced to Norbert Wiener and the science of cybernetics. Pask was asked by his professor to assist Wiener while he was visiting and giving his lectures in cybernetics to Cambridge students. According to Pask's wife, Elisabeth: "Wiener was describing the very science he [Pask] had longed to work on, but had not known what to call. He had known for some time that what he wanted to do was to simulate how learning took place, using electronics to represent the human nervous system […] in order to study how an adaptive machine could learn. Gordon decided to use his expertise in theatrical lighting to demonstrate the process." (Elizabeth Pask in Pickering, 2011).

6.1.1. The Musicolour Machine

While studying at Cambridge, Pask rekindled a childhood interest in theatre and joined the Footlights Club. Here he became involved in writing sketches, set design, and theatrical lighting, and it was from this milieu, combined with his passion for practical electronics and cybernetics, that Pask's first interactive learning device, the Musicolour Machine, was born (Pickering, 2011). In the early 1950s, off-the-shelf electronics were expensive and hard to come by. In order to build their nascent adaptive machines, Pask and his collaborator Robin McKinnon-Wood would cannibalise domestic electronics, mechanical devices (such as a calliope organ), and bits of bombsite computer technology, to build electronic devices that would lend themselves to theatrical performance. The early machines they built included a musical typewriter, a self-adapting metronome, and the Musicolour Machine (McKinnon-Wood, 1993).
Musicolour was a responsive light show that was designed to interact with the sound

input generated by an improvising musician. This thesis is primarily concerned with cybernetics as it relates to musical composition. However, the Musicolour Machine shares a common ontology and systemic similarities with a number of approaches used by cybernetic composers: the use of technology to aid in musical activity encompassing a distinctly performative ethos and the use of sound from the environment to drive a generative process, with feedback loops that thread back and forth between performer, technology and a musical output. Pask's emphasis on the design of interactions between human, machine, and environment also shares a particular similarity with the work of composers such as Agostino De Scipio and Roland Kayn.

The inspiration for building Musicolour also stemmed from Pask's interest in synaesthesia; he was intrigued by the possibilities of a machine that could detect patterns in sound and light and form relationships between the two (Pask, 1971). Furthermore, the interaction with a human performer was integral to the inception of the design. The machine was designed to 'listen' to a musical performer and transmute changes in pitch and rhythm to changes in lighting intensity and colour. However, the mapping of sound to light was not linear; it was designed in such a way as to encourage the musicians to adapt their playing to create aesthetically pleasing effects from the lighting array. The performer "trained the machine and it played a game with him. In this sense, the system acted as an extension of the performer with which he could co-operate to achieve effects that he could not achieve on his own. Consequently, the learning mechanism was extended and the machine itself became reformulated as a game player capable of habituating at several levels to the performers' gambits" (Pask, 1971).

Fig. 18. Musicolour's Circuit Diagram: Pask, Gordon: Musicolour, 1953-57, circuit diagram (Pask, 1971)

6.1.2. Musicolour Design & Operation

Musicolour worked by receiving a sound input from a performing musician. The signal was fed via a microphone to an amplifier and then passed through a bank of analogue band pass filters, which split the signal up into different frequency bands, thus the machine could register changes in pitch. Further filters were utilised to detect the rhythm and attack of each sound (Bird and Di Paolo, 2008). These filters are not specified, but it is most likely that they were a form of envelope follower, common to many subsequent modular synthesisers. The band pass filters were split into 8 bands which trigger specific lighting arrays to select different colours; we might imagine high frequencies triggering green, upper-mid frequencies triggering blue, lower-mid triggering red, and so on (the colours were selected mechanically using a servo-controlled, rotating colour wheel gel, which the light would shine through). The outputs of each filter were averaged over time using a root means squared operation (realised through analogue circuitry) to produce a threshold value. If the value exceeded the threshold, it would register as a 1, if not, then the value would register as 0. Thus, the threshold value would determine when a light would be on or off (Bird and Di Paolo, 2008). We may equate these threshold values to be internal criterions of stability as outlined in Chapter 3 of this thesis. However, the sound-to-light mapping was not directly linear, but adapted over time, as Andrew Pickering explains:

> "The internal parameters of Musicolour's circuitry were not constant. In analogy to a biological neurone, banks of lights would only be activated if the output from the relevant filter exceeded a certain threshold value, and these thresholds varied in time as changes built up on capacitors according to the development of the performance and the prior behaviour of the machine. In particular, Musicolour was designed to get 'bored' (Pask, 1971). If the same musical trope was repeated too often, the thresholds for the corresponding lighting pattern would eventually shift upward and the machine would cease to respond, encouraging the performer to try something new. Eventually some sort of dynamic equilibrium might be reached in which the shifting patterns of the musical performance and the changing parameters of the machine combined to achieve synesthetic effects" (Pickering, 2011).

Thus Pask and McKinnon-Wood had created an adaptive light show, which responded to sound in a non-linear way that was analogous to a biological response. Furthermore, the musician was able to 'train' the machine to respond in a way that was aesthetically pleasing to the performer. However, it is important to underline the non-linear nature of this adaptation, as Pask himself notes (Pask, 1971) that when a musical performer would initially interact with the machine it would respond in an obvious and knowable way, but as the machine would cycle through its adaptive mechanism ('get bored' and respond) it would change its behaviour and respond with increasing levels of abstraction, which the performer would continue to train while not being fully aware of what actions were facilitating what changes in the machine's behaviour; the performer would be aware that they were effecting a visual style from the lighting array and that this was representing a general mood in their performance. It is through this mechanism, this dance of agency, that Pask believes "the performer conceives the machine as an extension of himself" (Pask, 1971).

6.1.3. Ontological Theatre

In his 2011 book, *The Cybernetic Brain* (Pickering, 2011), Andrew Pickering uses the term ‘ontological theatre’ to describe how cybernetic machines such as Musicolour stage a particular ontology for us, one that is distinct from conventional modern norms. It is also worth examining this term in further detail, as it is a useful elucidation of how a machine can become an extension of one’s self and an equal partner in the creative process.

When considering how cybernetic machines stage ‘ontological theatre’ for us, we must first consider the peculiar non-modern ontology of cybernetics itself. As previously explored in this thesis, the philosopher Bruno Latour argues that modern thinking separates the natural sciences from the social sciences and thus a distinctly dualist ontology permeates modern thinking. Conversely, the multi-disciplinary science of cybernetics purposely crosses boundaries and thus demonstrates a non-modern ontology, in which, from an informational perspective, “people and things are not so different after all” (Pickering, 2011).

One of the distinct facets of this non-modern perspective is the rejection of notions of ultimate truth. This recognition of the ultimate unknowability of things reciprocates a performative ontology, one in which the world and the things in it are only meaningfully knowable through interaction. For the cybernetician this performative ontology manifests itself in the building of models or machines that replicate the behaviour of complex systems – such as Ashby’s *Design for a Brain* (1952) or his *Homeostat* machine (see Pickering, 2011) – and then interacting with them to discover their behaviour.

Cybernetic machines, such as Musicolour, are thus designed to be performative and to demonstrate things about the world in a performative context. Thus, Pickering’s term ‘ontological theatre’ describes how cybernetic machines or systems ‘act out’ this non-modern worldview. Pickering states that cybernetic projects stage ontological theatre for us in two senses: Firstly, as an aid to our ontological imagination, helping us to consider a different understanding of our being in the world (one that encompasses ultimate unknowability and a performative world view) and as an invitation to think that the world in general might operate in such a way. Secondly, cybernetic projects are examples of what might happen in practice if we adopt this non-modern imagining of the world and enact a performative ontology (Pickering, 2011).

To give an example of how the Musicolour machine ‘acts out’ this ontology, we can consider the fact that it is, in Beer’s terms (Beer, 1972), an exceedingly complex system, which interacts with another exceedingly complex system (the musician), and thus, in practical application, it demonstrates its own complex behaviour. Nonetheless, the wiring diagram for the machine is relatively straightforward in technical terms and there is no way we can know its complex behaviour by studying a graphical representation of the circuitry, or the circuitry itself; we can only know the behaviour of the machine by interacting with it and thus a performative ontology is enacted. Furthermore, the simple circuitry giving rise to complex behaviours enacts the cybernetic trope of exceedingly complex behaviours arising from very simple systems. From the cybernetic viewpoint this also theoretically begs the question; is the performer's behaviour, at its core, also derived from similar simple internal systems?

6.1.4. Cybernetic Art and Aesthetics

So Pickering uses the term 'ontological theatre' in connection with the Musicolour machine to describe how it enacts a performative, cybernetic worldview; quite literally Musicolour is "ontology in action" (Pickering, 2011). However, it is also worth noting that Musicolour was quite literally a theatrical object; a machine devised to stage a cybernetic ontology in a theatrical setting. It therefore acts as a good model for how a cybernetic machine in an artistic setting might operate technically, and it also places the contemplation of such a machine's performance into the realm of aesthetics.

For Pask, the interplay between human and machine and the pleasure that may be gained by such an interaction lay at the core of any consideration of aesthetics. However, Pask did not restrict his contemplation of aesthetics to interactions with machines; he attempted to encompass his critique of his own cybernetic art projects within a wider, more general view of aesthetics in art. Pask expounded his theory in a paper entitled "A comment, a case history and a plan" (Pask, 1971), in which he detailed the technical operation and artistic outcomes of two of his cybernetic art machines, the *Musicolour Machine* and the *Colloquy of Mobiles*. The latter machine was exhibited at the *Cybernetic Serendipity* exhibition held at the ICA in London in 1968. Within the paper he attempted to form a theory of aesthetics based on what he referred to as the "cybernetic psychology of pleasure" (Pask, 1971). Pask believed that humans are prone to seek out novelty in their environment, and having done so, they wish to control, find meaning, or come to terms with it, and in so doing, conceptualisations and abstractions arise. Pask states that as humans we find this activity inherently pleasurable and that the creative process and our interactions with the resultant outcomes are enacting this pleasurable activity. Pask believed that the role of an artist engaged in a creative endeavour should be to foster "aesthetically potent environments" (Pask, 1971). Pask used cybernetic expressions such as 'variety' to outline the terms of these environments:

> It is clear that an aesthetically potent environment should have the following attributes:
>
> a) It must offer sufficient variety to provide the potentially controllable variety (in Ashby's terms) required by man (however it must not swamp him with variety – if it does, the environment would be merely unintelligible).
> b) It must contain forms that a man can learn to interpret at various levels of abstraction.
> c) It must provide cues or tacitly stated instructions to guide the learning process.
> d) It may, in addition, respond to a man, engage him in conversation and adapt its characteristics to the prevailing mode of discourse (Pask, 1971).

While it was Pask's intention to make these precepts significantly broad to encompass all forms of art, attribute d) is what concerned him most. Pask's interest in adaptive learning machines and the process of learning itself led him to believe that the 'conversation' was the primary facet of meaningful interaction. This later led him to the formulation of his two career-defining hypotheses, "Interaction of Actors Theory" (Pask, 1992) and "Conversation Theory" (Pask, 1976), Attribute d) also points toward an artistic facet that might be better served by a cybernetic approach, namely that of a meaningful interactive experience. Andrew Pickering writes:

> "It is not the case that cybernetics *requires* us to do art in a different way. The analysis is not a condemnation of studio painting or whatever. But cybernetics does suggest a new strategy, a novel way of going on, in the creation of art objects. We could try to construct objects which foreground Pask's requirement d), which explicitly "engage a man in conversation", which "externalise this discourse" as Pask also put it – rather than effacing or concealing the engagement, as conventional art objects do. Cybernetics thus invites (rather than requires) a certain stance or strategy in the world of the arts that conventional aesthetics does not" (Pickering, 2011).

Furthermore, attribute d) implies a non-hierarchical formulation, one which shifts the power relationship between the artist and the audience and in so doing, again stages the ontology of cybernetics for us: "In contrast to the traditional impulse to dominate aesthetic media, the Musicolour machine thematised cooperation and revealing in Heidegger's sense" (Pickering, 2011). From these assertions we can assume that the tropes of 'conversation' and 'revealing' (in the terms Heidegger outlined in "The Question Concerning Technology"; Heidegger, 1954) are elevated in any consideration of aesthetics in cybernetic art.

6.1.5 Pask's influence

The Musicolour machine demonstrates how musical creativity may be enhanced through cybernetic means, but Pask's work also points toward how cybernetic art practice may be conducted and the particular ontology that is staged in doing so. In this sense, Pask's work is an important element of the cybernetic music canon. However, Pask's machines were also influential in a wider context. Pask exhibited the *Colloquy of Mobiles* at the *Cybernetic Serendipity* exhibition held at the ICA in London in 1968, along with other eminent artists and musicians such as John Cage, Karlheinz Stockhausen, Iannis Xenakis, Herbert Brün, Stafford Beer, Nam June Paik, and Peter Zinovieff (Reichardt, 1968). While many of the major musical figures among the contributors were confined to an LP that was released to accompany the exhibition, Pask's work took centre stage as the physically largest single work on display. The exhibition in London was seen by some 60,000 visitors and was shown on the BBC before it visited Washington DC and San Francisco (ICA, 2014). Andrew Pickering suspects that the public notoriety gained by Pask in this period implicates him as the model for the original Dr Who (Pickering, 2011), and his idiosyncratic mannerisms, dress sense and field of study certainly all suggest that this might well be possible. The artist, friend, and collaborator of Brian Eno, Peter Schmidt, curated the music for the ICA exhibition. While it is unknown if Eno visited the exhibition, it is certain that his interest in cybernetics chimed with Schmidt's and that cybernetics was a founding aspect of their friendship and collaborative work.

Pask's work is not only significant and influential for contemporary and subsequent computer artists and musicians, it also holds significance for current A.I. research:

> "Ideas that were dear to Gordon all that time ago, on interactive circuits with dynamic growth, are coming back in the form of neural nets, with parallel processing in digital computers and also analogue systems, my bet is that analogue self-adapting nets will take over as models of brain function – because this is very likely how the brain works – though A.I. may continue on its course of number crunching and digital computing. Surely this is alien to the brain. So we would fail the Turing test, being too good at pattern recognition, and much too poor at arithmetic compared with digital computers. In short, the kind of philosophy that Gordon nurtured does seem to be returning. Perhaps his learning machines have lessons for us now" (Gregory, 2001).

Because Pask chose his early forays into practical cybernetics to be artistic ones and because *Colloquy of Mobiles* in particular was well known to a discerning section of the public audience, it can be assumed that Pask's work and ideas were significantly more influential on artists working in the computer interaction field than the majority of his contemporary cyberneticians. However, Pask's later work on adaptive learning machines and his theoretical work on how learning takes place point beyond subsequent studies into symbolic artificial intelligence to a new model of how A.I. might be achieved. Pask's work was visionary and far-reaching and is still relevant to modern research and practice in this area.

6.2 Brian Eno

"I tend towards the roles of planner and programmer, and then become an audience to the results" (Eno, 1975b).

Born in 1948, Brian Eno is the best-known exponent of cybernetic music practices, particularly in the field of popular and avant-garde music. His work as a composer, musical collaborator, record producer and visual artist spans more than forty years and his understanding of cybernetics and complexity theory has influenced his practice from the very beginning of his career. As a self-confessed non-musician who trained in the visual arts, Eno has deliberately sought electronic and creative systems to aid him in expanding the possibilities of his musical composition.

6.2.1. Context and Compositional Perspective

Brian Eno was born in Woodbridge, Suffolk in 1948. After studying at Ipswich Art School and Winchester School of Art, he went on to join one of the most famous rock groups of the 1970s, Roxy Music. He has also released many albums as a solo artist and has worked as a producer and collaborator with some of the most commercially successful artists of the past forty-five years, including David Bowie, Talking Heads, U2, and Coldplay. He is also credited with inventing the genres of Ambient Music and Generative Music (Sheppard, 2008).

Perhaps the most important aspect of Eno's work as a composer is the ontological position he inhabits, and the fact that his work examines 'being' and 'emergence' as core themes makes it remarkable in comparison to traditional compositional norms. This ontological position, one he shares with other cybernetic composers, manifests itself in his working practice in a number of different ways:

1) Firstly, in the de-emphasis of the composer as author of a piece of music: the recognition that his compositional process is a non-hierarchical one, which incorporates human, machine, and environment equally. This is typified by his use of generative, mechanical, or computer systems, to which he relinquishes much compositional control. This de-emphasis represents a move away from the romantic and modernist perspective of the lone composer as the sole author and bestower of meaning on the work of music. Instead, Eno aligns himself with a post-modern or post-human, cybernetic perspective, which is exemplified by non-hierarchical, multi-authorship, and autopoietic creative processes.

2) Secondly, in the way that composition is subject to probabilistic process (as opposed to being entirely organised by a composer), and large and complex musical structures or behaviours can emerge from the probabilistic interaction of small sound elements. Again, this is non-hierarchical formation in which 'top-down' and 'bottom-up' organisational structures are of equal importance in the final compositional result. Eno's cybernetic music is also probabilistic in so far as it is different in each iteration. His compositions act like 'seeds' that 'grow' the structure of the music and like all organic structures, they are organisationally unique, but consistent in form: they are unique in each iteration, but adhere to a 'class of goals'. To use Eno's own example, each tree is different, but it still

belongs to the family of trees (Eno, 1996).

3) Thirdly, Eno views the 'frame' as being more important than the picture (Eno, 1996a); here he is referring to the context of the artwork (or composition) as having preference over the content (or musical notes). However, this extends to favouring the importance of production values over musical concerns, thus de-emphasising musical notes in favour of timbral composition (this shift was made possible through advancements in the recording technology that Eno utilises as a compositional tool). This aligns Eno with a non-modern, non-text-based ontology. This is akin to the ontology of McLuhan's post-literate society; in which the medium (rather than the text-based abstraction of notation) is the 'message' (Coyne, 1995). This shift in emphasis bears similarity to the 'process over product' ethic that was imbued in Eno as an art student, and which he continues to utilise in his compositions.

4) Finally, his ontological position manifests itself in the mode of listening he asks of his audience. Eno's music does not demand the attention of the audience; it sits in an environment. One may choose to listen to his music designed to enhance the ambient sound environment, or one may ignore it. The music blends with the environment and the resultant sound is contingent on this blend. Eno asks that the listener consider that the music, the listener, the technology, and the environment are all equal parts situated within the same system.

Each of these compositional perspectives is influenced and shaped by cybernetic thinking. In particular, Eno's art college tutor Roy Ascott and the work of the British cybernetician Stafford Beer, with whom Eno had a personal relationship.

6.2.2. Eno's introduction to cybernetics

Eno's first encounter with cybernetic ideas occurred after he left grammar school and enrolled in the art foundation course at the Ipswich College of Art, which at that time was entitled the Groundcourse. Taking a distinctively experimental approach to art education, the Groundcourse was designed and run by the telematic artist Roy Ascott. Ascott discovered cybernetics in the early 1960s and ideas concerning "information, interactive exchange, feedback, participation and systemic relationships were to form the basis of his [artistic and] pedagogical practice" (Pethick, 2006). He hoped that the Groundcourse would provide "a model for the relations between artist, audience and environment, and their positions within a wider social system" (Pethick, 2006). Ascott's cybernetic thinking was to see him move away from what he considered to be a reductionist worldview and toward a more 'open-ended', probabilistic perspective, which encompassed ideas of self-organisation and autopoiesis into artworks. He utilised this new ontological position to form a new kind of art course, first at Ealing Art College and later at Ipswich. Ascott's pedagogy and cybernetic vision, proved to be formative in Eno's development as an artist, and in the formulation of his subsequent approach to musical practice.

In order to examine his influence on Eno's work, it is relevant to examine Ascott's cybernetic beliefs in more detail. During the early 1960s, Ascott's work focused on interactive art, which the viewer was able to change in order to create new arrangements. Inspired by cybernetics, he took a holistic view of his practice, in which he saw his teaching as an extension of his studio work and where each fed back into the other in a 'mutually reinforcing system' (Ascott, 1964). Ascott outlined his cybernetic and artistic manifesto in a paper entitled *The Construction of Change* (Ascott, 1964). Here he established some of his fundamental artistic beliefs: firstly, that all art is didactic; secondly, that behaviour and control are key facets in artistic creation; and thirdly, that this should be understood using the science of cybernetics.

In this paper Ascott asserts that cybernetics is a multidisciplinary science, whose focus is on finding common control and communication mechanisms, which Ascott associated with artistic process and method. To this end he employed teachers on the Groundcourse from many different disciplines: "a biologist, a behavioural psychologist, an engineer, a sociologist and a linguist; the students also studied cybernetics and behavioural sciences. These various disciplines interacted to suggest new fields of study. Visiting tutors to the course included Gustav Metzger, whose auto-destructive art theories inspired a young Pete Townshend (guitarist with The Who) and Gordon Pask (an early pioneer in cybernetics), who became a collaborator of Ascott's" (Pethick, 2006).

Ascott opens *Construction of Change* with an examination of the cyclical nature of the process of making art, the meaning of the artwork and the role of the spectator within his own practice: "I make structures in which the relationships of parts are not fixed and may be changed by the intervention of the spectator. […] The participant becomes responsible for the extension of the artwork's meaning" (Ascot, 1964).

In an attempt to rationalise the need for cybernetic practice, Ascott argues that society is undergoing massive scientific and technological change and that culture and art shape and regulate society. It is therefore the artist's "moral responsibility" to attempt to interpret this change. The artist symbolically represents man's freedom to shape, change and control his world. Ascott believes that the *integrative* science of cybernetics offers the artist the best way to understand his own processes, how these shape the world, and how the world shapes the process. He states that cybernetics is "a coordinator of science as art is the coordinator of experience" and that this cybernetic viewpoint is not only changing our world, but "presenting us with qualities of experience and modes of perception that radically alter our conception of it" (Ascott, 1964).

To give further credence to the value of cybernetics in practice, Ascott outlines in detail the pedagogic methods of the *Groundcourse*, which were initially designed to break apart preconceptions: students were faced with "problems that seem absurd, aimless, or terrifying" and it was hoped that "out of this flux, a many-sided organism may evolve" (Ascott, 1964), which would subsequently lead to the formulation not only of original ideas, but continued inquiry, subversion, deconstruction, and growth.

In order to extend his vision of "process over product" (Ascott, 1967) in artistic endeavour, Ascott's public commentary on cybernetics did not only concern the visual arts, but also encompassed experimental music. In 1966 he wrote an article for the international scientific journal *Cybernetica* that included a discussion on the music of John Cage and in particular his defocusing of the score and emphasis on the process of music making. He cites the writings of John Cage: "If music is conceived as an object, then it has a beginning, middle and end, and one can feel rather confident when he takes measurements of time. But when it (music) is a process, those measurements become less meaningful…" Cage further asserts: "We must arrange our music so that people realise that they themselves are doing it, and not that something is being done to them" (Cage in Ascott, 1966). Technology historian and commentator Christina Dunbar-Hester believes that this selection of Cage's writing represents Ascott's uncovering of Cage's cybernetic intention: "Thus, the entire process of composition and performance is conceived of as enrolling the performers, the instruments, and the audience into a 'system' of experience that is distinct, and experienced as subjectively unique, and yet is part of an ongoing process" (Dunbar-Hester 2010).

Eno's early encounter with cybernetics was of a very practical nature; the Groundcourse was in essence a series of techniques for producing artistic ideas via generative processes. In the 'process over product' model, students were encouraged to think about their practice in a systematic way, through a series of tasks and problem-solving exercises. In some cases these were extreme. For example, in one instance students were asked to act out an alternative personality for ten weeks, and in another, students were locked in the gymnasium and subjected to loud music, flashing strobe lights, and marbles thrown on to the floor (Pethick, 2006). The methods of discombobulation favoured by Ascott and the Groundcourse were transformational in altering the worldview of many a student and Eno was no exception. The influence is demonstrated not only in his ubiquitous systemic approach to music making, but also in the cybernetic path of his future enquiry and practice.

6.2.3. Generating and Organising Variety in the Arts

After completing the Groundcourse, Eno studied for his degree at the Winchester School of Art, graduating in 1969. During his time at Winchester, Pete Townshend gave a guest lecture about the use of tape machines by non-musicians and Eno is said to cite this as the catalyst for him wanting to make experimental tape music (Townshend, 2012). He bought two second-hand Revox reel-to-reel tape recorders and began to experiment with sound. Under the influence of tutor and friend Tom Phillips, Eno began to develop an ardent interest in contemporary, experimental, and avant-garde music, in particular the works of John Cage, Terry Riley, and Steve Reich (Sheppard, 2008).

Acting on this newfound enthusiasm, Eno joined Cornelius Cardew's Scratch Orchestra; an experimental performance group initiated by the composer. At Cardew's insistence, both musicians and non-musicians were active members. Eno was a participant in a recorded performance of Cardew's *The Great Learning, Paragraph 7* (1971). He was to later pronounce that this experience was his "own personal discovery of complexity theory: the idea that complex, self consistent systems can derive from very simple initial conditions and quickly assume organic richness" (Eno, 1996a).

These influences were later examined in a paper Eno wrote for *Studio International*, entitled: "Generating and Organizing Variety in the Arts" (Eno 1976). Here he explores his interest in self-generating and self-regulating systems. Very much in the mode of Ascott's writings, Eno proposes that cybernetic theories may be applied to creating music, and contrasts experimental composition and performance with formal classical approaches. The paper offers a new, cybernetic way of thinking about experimental music that transcends classical boundaries.

He states that musical scores are a statement about formal organisation, and that classical orchestras have a militaristic hierarchy, which constrains behaviour, creates focus (a foreground and background), suppresses variety, and engenders predictability due to the training of the individual players (Eno, 1976).

Eno uses the term 'variety' (Ashby, 1956) in its cybernetic context: "the variety of a system is its total range of outputs, its total range of behaviour" (Eno, 1976). An organism's adaptability and flexibility, in response to an environment, is a function of the amount of variety it can generate. The capacity to recognise and respond to variety is essential in creating viable organisms and in the successful adaptation of an organism to a dynamic environment. Enough variety must be incorporated in an organism to allow for deviation and adjustments that are useful in adaptation and survival. Variety also plays a vital role in mutation and evolution. Eno contends that the primary focus of experimental music has been towards its own organisation and as a consequence it is subject to cybernetic principals such as variety. Furthermore, unlike classical (or avant-garde) music, experimental music does not offer instructions toward highly specific goals or necessarily repeatable results. However, he draws a distinction between indeterminate music and experimental composition, which seeks a 'class of goals' rather than 'goalless behaviour'.

The exemplar of Cornelius Cardew's "Paragraph 7" from *The Great Learning* is used in Eno's paper as an expression of these self-organisational principles. He describes how the set of (seemingly indeterminate) instructions in the score, which do not stipulate organisation, give rise to a set of 'automatic' controls that are "the real determinants of the nature of the piece" (Eno, 1976).

The score of "Paragraph 7" is deceptively simple: each singer in the choir is given a short text, taken from Confucius. Directions are given stipulating that each word or phrase be sung a number of times in a linear sequence. However, it is instructed that each member of the choir sings each phrase on the "length-of-a-breath note" (Cardew, 1969), which means that the length of each individual performer's note is determined by the length of their breath, and not by a predetermined meter. Another crucial, self-governing instruction for the score is that each note sung by a performer must be a note that is heard being sung by a colleague. So that the pitch at which each performer sings is determined by the loudest note heard by each singer. Another stipulation is that that no individual performer must sing the same note consecutively; the performers must change the note each time a new note is sung.

Eno points out that there are specific differences between what one might imagine an idealised performance to sound like and what happens in an actual performance of the piece. Firstly, he notes that because the piece has so little instruction and is also performed by a group of performers, many of whom are amateurs and therefore more unpredictable, one might imagine that the piece is very different each time it is performed. Secondly, he suggests that in an ideal performance one might rightly assume that the piece begins very discordantly and that over time the piece will settle down into some kind of harmonic concordance, but that this will take a significant amount of time as each discordant note option is eliminated. However, in the actual performance (Cardew, 1971), harmonic accord is achieved much more quickly and, once the piece has "settled" harmonically, it sounds much more musically structured and interesting (has more variety) than one might imagine.

He postulates that this happens for several reasons. Firstly, there are a number of *variety enhancers* in action. For example, there are some non-trained (tone-deaf) singers in the choir, which means that when choosing to sing the note of the nearest colleague, they may inadvertently sing a discordant note, which introduces greater variety. Secondly, a singer may unconsciously choose an octave or harmonically related note, rather than the exact same note, because it is more within their singing range. And finally, *beat frequencies* are occurring, where two almost identical notes are being sung, thus causing a third note to sound, which is not harmonically related to the first two (Eno, 1976).

However, Eno notes that there are also 'variety reducers' in action (other than those stipulated by the score). Firstly, the resonant frequency of the room will exaggerate (make louder) any note that is sung at this frequency. Because of the self-governing nature of the score "sing the loudest note you can hear"; Cardew, 1969), it is much more likely that the pitch of the piece will settle around the resonant frequency of the room. Secondly, he cites 'taste' as a fundamental variety reducer in this case: "it is extremely difficult unless you are tone-deaf (or a trained singer) to maintain a note that is very discordant with its surroundings" (Eno, 1976), and these combined factors explain why the initial discordant notes in the piece rapidly thin out and quickly settle into a more harmonious chord.

Eno concludes from this that rather than ignoring or subduing the variety that is generated in performance (as is the case in classical composition), variety is really the substance of this piece of music. He goes further to describe what he believes to be "the most concise description of this kind of composition, which characterises much experimental music" (Eno, 1976), namely the statement by Stafford Beer,[20] which describes cybernetic design practice. Beer wrote: "instead of trying to specify it in full detail, you specify it only somewhat. You then ride on the dynamics of the system in the direction you want to go" (Beer, 1972). In the case of the Cardew piece, the "dynamics of the system [lie in] its interaction with the environment, physiological, and cultural climate surrounding its performance" (Eno, 1976). Eno believes that Beer's statement is not only "the most concise description of this kind of composition", but also one of the central epithets of Beer's thesis, which Eno applies in his own autopoietic compositions.

[20] Returned to as a recurring theme in this thesis as an apposite descriptor of cybernetic compositional practice.

In discussing Cardew and Cybernetics in interview, Eno states:

> "Cybernetics and systems theory are mechanisms by which you can explain this piece. It has strong parallels with biological systems, which again aren't governed by external controls. How do systems like this keep themselves intact? In fact, all systems of this nature are what's called autopoietic, which means they tend to maintain their own identity.
> In the old method of composing, you specify the result you want, and then you present a number of exact instructions to get there. The Cardew piece is radical because he doesn't do all that, and yet it happens. The behaviour remains governed. Political systems are all doing what the old composers were doing. By a system of laws and constraints, they attempt to specify behaviour. They're all saying, 'What kind of society do we want?' Then they say, 'All right, so lets constrain this behaviour here, and let's encourage this behaviour here.' They're trying to govern highly complex systems by rote. And you don't need to do that. Instead of trying to specify what you want in full detail, you only specify somewhat; then you ride the dynamics of the system in the direction you want to go. There are certain organic regulators; you don't have to come up with them, you just let them operate.
> One of the central ideas of cybernetics is that the system itself will inevitably produce a certain class of results" (Eno in Armbruster, 1984).

Eno's examination of *The Great Learning* is germane as it also details his own approach to cybernetic music, namely that the simple initial conditions of a complex system may be specified by the composer and that they will act as a 'seed' that will grow the composition. This will produce musical results that have a different outcome each time the system is run, but each iteration will still adhere to a class of results.

Eno expands the scope of his paper by providing further examples of this type of composition, citing the work of Michael Parsons, Michael Nyman, and Gavin Bryars. He mentions another feature of these examples, namely the 'fade-out' or 'fade-in' endings and beginnings to these pieces. He believes that this feature has an effect on the listener, giving the perception that these pieces of music exist in a hypothetical continuum, of which we may only be perceiving a part – there may be other permutations and outcomes – and that they do not exhibit a strong feeling of progress or resolution (Eno, 1976). The idea that the fade-in creates this viewpoint for the listener strongly associates these works with an ontology of becoming or emergence; the pieces exist in an evolving continuum, where there is no clear and fixed goal as there is in other types of music, yet they exhibit emergent qualities that are perceived as music. Furthermore, Eno states that experimental music is about the interrelation of a limited number of elements in time and the different permutations that may result. He also notes that these tend to be organised in cyclical forms and are often based on 'found materials', which he believes focuses the composers mind to the reorganisation of this material and thus into the cybernetic framework that he is proposing (Eno 1976).

It is notable that not only are all the composers that Eno is citing English, but also that most of them were known to him on a personal basis. It is also significant that the emergent classification of music existing 'in a continuum' that Eno is outlining here is also a description of his own work at this time, in particular *Discreet Music* (1975), and his collaboration with the guitarist Robert Fripp, *No Pussyfooting* (1973).

The formation of Eno's own record label, Obscure Records, in 1975, and its subsequent release not only of his own records, but also of recordings (that he produced) of compositions by Gavin Bryars, Christopher Hobbs, Michael Nyman, and David Toop, would tend to suggest that within this paper, Eno is attempting to create a cybernetic manifesto of sorts, one that echoes Ascott's, and which describes a certain type of experimental music, with which he is intimately involved in making, promoting, and curating.

The fact that his paper is a *cybernetic* manifesto and not strictly a musical one is made more evident in Eno's non-hierarchical assertions about music: instead of experimental and classical music being oppositional, or one essentially usurping the other, they both exist on a "scale of orientations" (Eno, 1976). Some classical forms such as a piano sonata leave a lot of room for interpretation (in areas such as tempo, dynamics, musical phrasing, etc.), and certain types of experimental music are very prescribed, or at the very least constrained by the laws of physics (such as Alvin Lucier's *I Am Sitting in a Room* (1969), for example). Moreover, he makes a further cybernetic distinction, namely that some forms of music are organised in an algorithmic form and others are organised heuristically (he uses direct quotes from Beer to explain these terms). That is to say that some forms of composition are algorithmic – organised in a highly prescriptive way, with immutable, clear and fixed goals – while others are heuristic – they have a set of simple instructions or constraints that produce a class of goals (different in each performance, but which adhere to a set of outcomes that are perceptibly coherent). Eno likens this heuristic creative approach to processes at work within living organisms, who rather than ignoring their environment (as a composer would in classical composition), instead regard the environment and its irregularities as a "set of opportunities around which it will shape and adjust its own identity" (Eno, 1976).

The final paragraph of the paper echoes Ascott once again in its evoking of cybernetics in art as a solution for interpreting rapid technological change. It is worth noting that in concluding his paper he quotes from Morse Peckham (one of Ascott's favourite philosophers and also popular among other Groundcourse alumni, such as the artist Stephen Willats (Nikolic and Russo, 2012). Eno asserts: "In his book *Man's Rage for Chaos,* Morse Peckham writes: 'Art is the exposure to the tensions and problems of the false world such that man may endure exposing himself to the tensions and problems of the real world' [Peckham, 1967]. As the variety of the environment magnifies in both time and space and as the structures that were thought to describe the operation of the world become progressively more unknowable, other concepts of organisation must become current. These concepts will base themselves on the assumption of change rather than stasis and on the assumption of probability rather than certainty. I believe that contemporary art is giving us the feel for this outlook" (Eno, 1976).

Here, Eno not only recalls Ascott's "scientific and technological change" argument for embracing cybernetics, but also expounds the unknowability of an increasingly complex world. This is concordant with Stafford Beer's view of the ultimate unknowability of exceedingly complex systems and the 'black box' ontology expounded by many prominent cyberneticians such as Norbert Wiener, Ross Ashby, Gordon Pask, and others, namely that the universe is full of 'black boxes', whose true workings we do not (and may never) fully understand. These range from the obvious (the human brain) to the mundane (Ashby gives the example of a child opening a door). We are unaware of the inner mechanisms at work in many systems, but we encounter them everyday and may only understand them through performative action in the world (Pickering, 2011). Furthermore, when Eno states "These concepts will base themselves on the assumption of change rather than stasis and on the assumption of probability rather than certainty", he firmly places his conclusion in the ontology of becoming or emergence, which is so synonymous with cybernetics.

6.2.4. Eno and Stafford Beer

There is no doubt that Eno would not have written this paper under Ascott's influence alone. Indeed, the many quotes from Stafford Beer point to the source of much of the theory underpinning Eno's thesis, namely Beer's book *Brain of The Firm* (1972). However, the originality of Eno's work here should not be undervalued; although a number of his musical contemporaries were engaged in what could be described as cybernetic practice, very few wrote about what they were doing in a cybernetic context or defined their work in this way. Furthermore, none put forward an overarching thesis of experimental music as cybernetic practice, which points toward a mode of composition that is quite distinct and has a markedly non-modern ontology.

Eno came across *The Brain of the Firm* in 1974 and utilised it as the basis of his paper. While Eno claims to have knowledge of other cyberneticians' works, he states that *Brain* is the only book he has ever read in any detail on the subject (Whittaker, 2003). However, this fact should not diminish his understanding; the first five chapters of *Brain of the Firm* are a general introduction to cybernetics that includes reference to the work of Norbert Wiener, Ross W. Ashby, Warren McCulloch, Claude Shannon, and other founding fathers of cybernetics. He subsequently wrote to Beer including a copy of the essay as he thought Beer might be interested in "this unusual application of his ideas" (Whittaker, 2003).

Following this introduction, Eno met Beer on two occasions, once at Eno's flat in London in 1975, and again in 1977 at Beer's cottage in the Welsh countryside. Both encounters were characterised by long discussions of Beer's ideas (Whittaker 2003). During the Welsh meeting, Eno remembers that Beer asked him to be a public exponent for cybernetics: "I carry a torch, a torch that was handed to me along a chain from Ross Ashby, it was handed to him from Warren McCulloch… I want to hand it to you, I know it's a responsibility and you don't have to accept, I just want you to think about it." (Eno quoting Beer in Whittaker, 2003). Eno recalls this as being a very strange request and politely declined the invitation, but this incident does demonstrate the strength of feeling Beer had toward Eno's work and perhaps Beer also saw Eno's potential as a well- known advocate for cybernetics 'spreading the word' to the general public.

Despite Eno's rejection of Beer's proposal (Whittaker, 2003), cybernetics has remained a strong and influential force in Eno's work. He states that it is "one of the most important bodies of theory in my life, it's still a very underexploited and unrecognised body of work… It's still very current to me" (Eno in Whittaker, 2003).

He also cites that Beer's work was a significant influence on his systems recordings and on *Discreet Music* (1975) and *Music For Airports* (1978), in particular (Eno in Whittaker, 2003).

6.2.5. Eno and The New English Music

Before exploring some of Eno's overtly cybernetic pieces it is important to examine some of his earlier musical practice and trace the development of the cybernetic working methods he established. While Eno's route to cybernetic music was arguably predestined by his art school exposure, there are a number of interesting musical collaborations that helped to shape Eno's understanding of music and of the possibilities of cybernetic music making. While participating in the Scratch Orchestra, Eno also became a member of the Portsmouth Sinfonia (in which he amateurishly played clarinet). Modelled on Cardew's Scratch Orchestra, the Sinfonia was also a group of musicians and non-musicians, who attempted to play an established repertoire of well- known movements from classical pieces such as the *William Tell Overture*, Strauss's *Also Sprach Zarathustra*, and Grieg's *In The Hall of the Mountain King* (Sheppard, 2008). The Sinfonia gained notoriety as the "world's worst orchestra" (Sheppard, 2008), through a number of memorable performances and record releases, two of which Eno produced. Eno made some important connections with other members of the ensemble, most notably Gavin Bryars – who conceived of and ran the orchestra – and Michael Nyman, both of whom would later release their first records through Eno's Obscure label in the mid-1970s. Although the sound the Sinfonia produced "would regularly reduce audiences to convulsions of tear-streaming laughter" (Sheppard, 2008), there was a seriousness to elements of the endeavour, in particular in the desire to rescue the orchestral canon from its bourgeois, elitist constituency, and also in Bryars' desire to utilise "mistakes" in the creative process.

6.2.5.a. Honouring Error and The Cult of The Beautiful

Michael Nyman sees Bryars' work of this period as belonging to an English movement of experimental music that was making a transition from the indeterminacy expounded by John Cage and The Fluxus Movement into Minimalism and a new tonality, and which Nyman refers to as the "cult of the beautiful", which began to develop in the late '60s and early '70s (Nyman, 1999). In America, this shift took the form of highly controlled musical systems and demonstrated influence from non-Western musical forms, exemplified in the rhythmic, repetitive and drone-like qualities of the work of Terry Riley, Philip Glass, and La Monte Young. However, in England the "return to melody" (Nyman, 1999) was achieved by composers tending to draw on Western musical traditions, often using recordings or scores from the classical canon as the basis for musical pieces. However, Nyman asserts that it is "far less easy to make a hard and fast distinction between 'indeterminacy' and the 'new determinacy' in England than it is in America" (Nyman, 1999). English composers, such as Cardew and Bryars, tended to adopt a looser approach to determinacy, one which, in structure, displays similarities to Eno's cybernetic use of heuristics (as opposed to algorithms) in his music-making process.

This 'looser' version of the new determinacy and emphasis on melody, adopted by the English composers, is seen in a number of Bryars' works from this period, such as *The Sinking Of The Titanic* (1969) and *Jesus' Blood Never Failed Me Yet* (1971), works which formed the respective A and B Sides of the first release on Eno's Obscure label: Obscure no.1, 1975). These pieces utilise "found" recordings that are played within the performance along with an ensemble of live players. *The Sinking Of The Titanic* is an 'indeterminate' piece in which players improvise with a number of tape sources associated with the Titanic in order to create the music. The determinacy of *Jesus' Blood Never Failed Me Yet* is found in the players attempting to adapt to the meter of a field recording made of a homeless man singing a well-known religious song. Both pieces are melodic, evocative, and moving – a feature the composer expressly wished to convey (Bryars, 1998) – but which was atypical of the experimental music of this era.

Eno's biographer, David Shepherd, believes that rather than the melody, it was the nature of the indeterminacy – the "mistakes" – that caused audiences to find performances of Bryars' Portsmouth Sinfonia so moving: "Humour was always central to Sinfonia activities, but despite their inherent eccentricity, their collective tongue was never completely stuck to its check. This became more apparent when their flailing attempts at the classics unerringly produced music of naive, crippled poignancy that many found unfeasible moving" (Sheppard, 2008). While *Titanic*, *Jesus' Blood*, and the Sinfonia were all melodically different, they shared this sense of "naive, crippled poignancy" gained through compositional systems that deliberately engendered mistakes.

The use of this type of determinism, one formed from restrictions or mistakes, is reflected in one of Eno's best-known maxims; "Honour thy error as a hidden intention" (Eno and Schmidt, 1975). He first used this axiom as an instruction on one of his *Oblique Strategies* cards, which were developed in collaboration with the visual artist Peter Schmidt. First published in 1975, the cards are a series of instructions or maxims designed to be used in creative situations to expand the range of possibilities and to assist the participants to view their creative process in a new light (Taylor, 1995). Eno has used the cards many times both as an artist and producer and they have become more widely known among record producers and engineers (Taylor, 1995). When discussing Eno's production methods and the use of the Oblique Strategy cards, David Bowie stated: "Brian is a born cybernetician. He will take the most unlikely juxtapositions and philosophical ideas and throw them together into this kind of conceptual stew of his and produce this unfathomable, but fascinating animal. And he will continually stop and re-evaluate the work that's been done and then throw it in an entirely unexpected direction" (Sischy, 1995).

While the cards share similarities with exercises prescribed to Eno while on the Groundcourse and can be seen as cybernetic in many senses, the interesting element here is that Eno perceived errors or mistakes as an important part of the creative process. Beer believed that mistakes were an essential part of any learning system. He defined heuristics as "a set of instructions for searching out an unknown goal by exploration, which continuously or repeatedly evaluates progress according to some known criterion" (Beer, 1972). In other words, a process of trial and error in which 'mistakes' are an inherent part of exploration or experimentation. Bryars' work with this type of "new determinacy" influenced Eno in this regard and this was the first instance of Eno witnessing at first hand how 'mistakes' could be incorporated and built into the compositional process. Furthermore, this view of error as an intrinsic part of the artistic process is an acknowledgement and embracing of the probabilistic process at play within the compositional process.

Eno also cites another quality of the Sinfonia's music, one that chimes with the qualities of his own ambient music: "What was interesting about this mix [of competent and incompetent musicians]… You'd hear a melody of whatever it was, hidden somewhere among all those approximations of the melody. It was like a blurry version, a soft focus version, of classical music, and it produced some beautiful music" (Aikin, 1985). This quotation demonstrates a recognition of the approximations (probabilistic processes) at play in the musical composition and that in this context they have emergent properties that can produce "beautiful music".

The evidence suggests that Eno's work of this period and his development of Ambient Music comes from and exists within the new English music movement that Nyman describes. Eno's own reference to "beauty" as an aesthetic consideration in his music (Eno, 1996a) and his direct involvement in the production and record releases of many of the English composers of this movement (including, in particular, Bryars, Nyman, and Hobbs) on his Obscure label and his use of probabilistic, "new determinacy" systems in his music making, are all evidence of Eno's immersion in the new English music movement of this period. It is also notable that he recognised that these facets of experimental music coalesced with his vision of cybernetic music.

In retrospect, this movement of "minimalist" English composers can be seen as taking a more affirmed leap into postmodernism than their American contemporaries, particularly in their use of found sound and the recycling of popular classics. In many ways, the creative direction of the English movement was a fortuitous stepping-stone for Eno's move into the post-humanist ontology of cybernetics.

6.2.6. Eno's Formulation of Cybernetic Musical Practice

In order to examine Eno's cybernetic musical practices we must turn to his compositions that utilise technology and that have an overt human/machine/environment axis at play in the compositional process.

6.2.6.a. Cybernetics & Roxy Music

Eno appears to clearly delineate between his time in Roxy Music and all his other musical endeavours; he has never written about his involvement in Roxy Music in a cybernetic or musically analytical context. However, there are some notable features of his work with the band that exhibit overtly cybernetic characteristics and these manifest themselves in two ways: Firstly, in his use of the synthesiser as a modulating device. Eno's first encounter with the synthesiser was through Andy Mackay, the saxophone player in Roxy Music, who lent Eno his EMS VCS3 in the initial stage of the group's formation (Sheppard, 2008). The instrument was invented by Peter Zinovieff and David Cockerell in 1969. The VCS3 was notable as it was not only one of the first commercially available synthesisers with an affordable price tag, but it was also the first portable synthesiser (Boddy, 1994). One of the most interesting features of the early iterations of the VCS3 was that there was no musical keyboard. This not only attests to the exoticness of this instrument as a musical device but it also points to the mode of its practical use, namely that of a modulating device for input sound sources or as a tool for creating 'non-musical' sound effects and atmospheres. There are a number of other important features of the VCS3's design. All other analogue modular synths contemporary to the VCS3 were of the traditional 'boxes joined together with wires' design. Here, signals from oscillator to envelope, or to filter, were transmitted via cables that could be plugged from one module to another to form a patch that constituted the resulting sound. Conversely, the VCS3 used a non-wire-based matrix patch bay. Here, a series of pins stuck into a circuit board determined how signals from the modules were connected together. This allowed for more flexible and immediate experimentation and manipulation of sound sources. Another unique feature of the VCS3 was that in place of a musical keyboard, there was a joystick, which allowed the operator to change pitches or settings, or to morph between parameters, depending on how this control device was assigned in the matrix. This feature also allowed for very quick and versatile experimentation with sounds input from a microphone, or another external source such as a guitar.

Of the VCS3, Eno is quoted as saying: "The thing that makes this a great machine is that […] you can go from the oscillator to the filter, and then use the filter output to control the same oscillator again […] It feeds back on itself in interesting ways, because you can make some complicated circles through the synthesiser" (Eno in Pinch and Trocco, 2002). While Eno utilises the ubiquitous cybernetic trope of feedback in this statement, Andrew Pickering believes that Eno is evoking it here to describe another feature of the synthesiser: feedback as described here is not "that which enables control of some variable (as in a thermostat), but as that which makes a system's behaviour impenetrable to the user" (Pickering, 2011). The matrix of possibilities set up by the feedback loops within the machine is so complex that one cannot predict the outcome of the sound experimentation. In other words, the synthesiser, in this instance, is a 'black box' device; it is only by creative exploration that one can *find out* what sounds may be produced. Thus a performative, cybernetic ontology is invoked.[21] Pinch and Trocco further elaborate on this interaction: "the resulting music was an exchange… between person and machine, both contributing to the final results. This may be why analogue synthesists can readily recount feelings of love for their synthesisers" (Pinch and Trocco 2002). Pickering also believes that Eno's work with the VCS3 in Roxy Music demonstrates a continuity between his practice here and his later work: "Eno was riding the dynamics of a generative system – the synthesiser – which he could not fully control. What he learned from Beer was to make this cybernetic insight explicit and the centre of his future musical development" (Pickering, 2011).

The second way in which Eno's cybernetic practice manifested itself in Roxy Music was through live performance with electronics: In the early 1970s, live performance with electronics in popular music was almost unheard of, and it was almost

[21] Here we may see a direct parallel to Kayn's use of the synthesiser described in section 5.5 of this thesis.

exclusively limited to the use of the synthesiser as musical instrument in performance (Holmes, 2012). In the early stages of Roxy Music, Eno, the 'non-musician', transmuted from 'sound recordist' to 'sound manipulator', feeding guitars, keyboards and vocals though the VSC3 to be distorted, modulated and manipulated (Sheppard, 2008*).* Eno's electronic equipment was not limited to the synthesiser but also included two Revox reel-to-reel tape machines, a Ferrograph tape recorder, an Ampex tape recorder, and a customised delay echo unit. He would take up position at the mixing desk during concerts and manipulate the sound of the band in real time (Sheppard, 2008*).* Andy Mackay recalls: "when we first started, we didn't really have amps on stage. I know it sounds ridiculous, but there was a point where we used to just be DI-ed [directly injected] through his [Eno's] synths, a mixing desk, and he'd be out in the audience mixing. It was incredibly unsatisfying, because you couldn't really hear what you were doing. And then what you were doing bore no resemblance to what was coming out, so we soon abandoned that. That was probably the most extreme. That was pretty far out for 1972…"(Sheppard, 2008*).* This statement highlights that what Eno was attempting with this kind of sonic manipulation was more akin to a David Tudor, Gordon Mumma, or John Cage type of live performance, with live instruments and technology. It also demonstrates the degree to which the performance was being mitigated by the technology. The additional fact that this was in real time and that the outcome was ephemeral and not fully determinable also points to the cybernetic ontology underpinning Eno's practice at this time.

6.2.6.b. Eno's Progressive Rock Albums

After leaving Roxy Music in 1973, Eno embarked on a successful solo career writing and producing a number of progressive rock albums. While the techniques employed on these albums are interesting to the extent that their outcomes are shaped by process and mitigated by technologies that are not without cybernetic merit, they are primarily concerned with the compositional process and techniques of popular music composition, which has its own rules and strictures. These may at times coalesce with cybernetic ideas but they are seldom the guiding principles engaged in the songwriting process of this genre. They are also not experimental in the terms that Eno outlines in *Generating and Organizing Variety in the Arts*. Nonetheless, the processes engaged in writing these albums were far from conventional, in the case of the employment of the Oblique Strategies cards, for example, or Eno's phonetic, Hugo Ball influenced lyric-writing technique. It is also worth noting that some of his songs lyrically allude to cybernetics, in particular *Everything Merges With The Night* (1975), which refers to the Chilean Allende government and in which Stafford Beer implemented the *Cybersyn* governmental system (Beer, 1995). While it is true to say that these popular music albums were not overtly cybernetic, the techniques Eno learnt while working on these records helped him to attain the technical skill required to engage the studio as a compositional tool (Tamm, 1995).

6.2.6.c. Ambient Music

Eno took advantage of his newfound technical competence in the studio and the emphasis of his recorded output during the 1970s began to alter. Over the course of his progressive rock albums, Eno began to include many more instrumental songs that reflected the technological possibilities the studio had to offer in the compositional process. During this period he also talked in interviews of wanting to shift music from "Portrait" to "Landscape"; defocusing away from the lead singer and bringing background elements forward. For example, on *Another Green World* (1975), only five of the fourteen tracks contain lyrics. Ultimately this was to lead him to realise that he was happier with no lead singer at all (Sheppard, 2008*).*

Eno's work with the guitarist Robert Fripp, particularly on *No Pussyfooting* (1973) was a strong precursor to Eno's Ambient Music, especially in the technological techniques involved. However, rather than a technological spur for its evolution, Eno cites a highly empirical origin for Ambient music:

> "I was confined to bed, immobilised by an accident in early 1975. My friend Judy Nylon had visited, and brought with her a record of 17th-century harp music. I asked her to put it on as she left, which she did, but it wasn't until she'd gone that I realised the hi-fi was much too quiet and one of the speakers had given up anyway. It was raining outside, and I could hardly hear the music above the rain – just the loudest notes, like little crystals, sonic icebergs rising out of the storm. I couldn't get up and change it, so I just lay there waiting for my next visitor to come and sort it out, and gradually I was seduced by this listening experience. I realised that this was what I wanted music to be – a place, a feeling, an all-round tint to my sonic environment" (Eno, 1996a).

Eno released four albums between 1978 and 1982 under the moniker of Ambient Music[22]. The musicologist and Eno biographer Eric Tamm describes Ambient Music as: "A gentle music of low dynamics, blurred edges, and washes of sound colour, produced primarily through electronic means" (Tamm, 1995). The first of Eno's Ambient albums was 1978's *Music for Airports.* Technologically, the album is in one sense a collection of tape-loop experiments. For example the first track on the album is a loop of soft piano playing, cut up and arranged in various configurations. Nonetheless, the mechanisms at work in the compositional processes are not evident in the sound of the resulting pieces, which have a clear aesthetic sensibility. Eno is known to have criticised the aesthetic of much overtly process-driven music, telling the well-known rock journalist, Lester Bangs: "I think the trouble with almost all experimental composers is that they're all head, dead from the neck down. They don't trust their hearts, I think, and tend to take themselves with a solemnity so extreme as to be downright preposterous. I don't see the point, really. I've always abandoned pieces which succeeded theoretically but not sensually" (Bangs, 1979). This said, *Music For Airports* is undoubtedly a 'process' record, in which technological systems are constructed and subsequently run to produce a class of possible goals. The prime exemplar of this method on this record is the 2nd track on the album, "2/1".

This piece of music was made in Germany in the studio of Conny Plank, a renowned record producer whose recordings of many 'Krautrock' bands, such as CAN, Cluster,

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22 Eno's ambient series consists of: *Music for Airports, Ambient 1(1978), The Plateaux of Mirror, Ambient 2 (1980), Day of Radiance, Ambient 3(1980) and On Land, Ambient 4 (1982)*

and Kraftwerk had been a major influence on Eno's pop music production. During his time at Plank's studio, Eno met Holger Czukay (student of Stockhausen and former member of the experimental rock group CAN). He was impressed with the tape cut-up techniques that Czukay was employing on his (Plank-produced) 1979 album, *Movies* (Sheppard, 2008). Inspired by Czukay's work, Eno set about re-imagining some piano recordings he had made of Robert Wyatt improvising during a previous recording session and these formed the basis of a number of tracks on the album. A different approach was adopted, however, on *1/2*: Eno and Plank invited some local female session singers to the studio to sing wordless 'aaahhs' in harmony over the looped piano note clusters, which modulated around the key of F Minor. The pianos were then removed and after the vocals had been subtly treated by passing them through a synthesiser (which added a small amount of noise and envelope, to shape the attack and decay of the notes), the individual vocal sounds were recorded onto separate lengths of tape between fifty and seventy feet long (Sheppard, 2008). To facilitate these long loops, the tape was spooled around metallic studio chair legs. Eno then recorded these non-contiguous loops back onto the multitrack tape: "I just set all these loops running and let them configure in whichever way they wanted to" (O' Brien, 1978). The complexity of the piece arises as each five-second vocal recording, recorded on to tape loops of differing lengths, at times coalesce to form chords and shifting melodies and at others leave silence or only individual notes. The aesthetic effect is of a rather sparse angelic choir, singing in a magically fluid way. There is no meter or pulse but the notes appear to interact in a knowing and predestined way; the structure seems designed but at the same time beguiling.

The aesthetic effect of this piece demonstrates Eno's preoccupation with what Nyman called the "cult of the beautiful" (Nyman, 1999), but it also sees him engaging in the "new determinacy" techniques employed by his contemporary, English experimental composers. However, Eno's version of the new determinacy is a strictly technological one, in which the timing and tone of the piece is mitigated by technological means. This is also a probabilistic process, but specifically designed to produce a class of goals. It is also noteworthy that the environment is active in the technological process. This is seen in the long tape loops, which are passed out from the tape recorder and spooled around objects such as metallic microphone stands and chair legs, the friction of which will alter the timing of each loop in a slightly unpredictable way (Tamm, 1995).

Another feature of this piece and almost all of Eno's ambient recordings is that they could not be achieved as a live performance with instrumentation or singers; only the recording studio could attain these results. In this context Eno sees his Ambient Music as being the apex of "the studio as compositional tool":

> "Psychedelia expanded not only minds but recording technologies, but there was still an assumption that playing with sound itself was a 'merely' technical job – something engineers and producers did – as opposed to the serious creative work of writing songs and playing instruments. With Ambient Music, I wanted to suggest that this activity was one of the distinguishing characteristics of the new music, and could in fact become the main focus of compositional attention" (Eno, 1996a).

Here we see Eno recognising that he is composing in a new way, one in which the technology enables and also heavily mitigates the outcome:

> "In a compositional sense this takes the making of music away from any traditional way that composers worked, as far as I'm concerned, and one becomes empirical in a way that the classical composer never was. You're working directly with sound, and there's no transmission loss between you and the sound – you handle it. It puts the composer in the identical position of the painter – he's working directly with a material, working directly onto a substance, and he always retains the options to chop and change, to paint a bit out, add a piece, etc. […] You can do what the classical composer couldn't: you can infinitely extend the timbre of any instrument. You are also in the position of being able to subtract or add with discrimination: you can put an echo on the bass drum and not on anything else" (Eno, 1983).

On the liner notes of the album *Discreet Music* (1975), which predates the ambient series, Eno states: "I was trying to make a piece that could be listened to and yet could be ignored... perhaps in the spirit of Satie, who wanted to make music that could 'mingle with the sound of the knives and forks at dinner'" (Eno, 1975). While it is clear that Eric Satie's "Furniture Music" was very influential on both the sound and ethos of Ambient Music, what makes it distinctive is not only its technological process, but also the emphasis on timbre over melody. Eric Tamm refers to this as Eno's "vertical colour of sound" (vertical pertaining to harmonics and colour pertaining to timbre), which Tamm argues is Eno's keenest interest in the compositional process (Tamm, 1995). This is perhaps because, as a non-musician, Eno's instrument of choice is the studio and 'making it sound good' by altering timbre is one of the primary functions of the recording studio. Altering timbre over time will create a sense of movement and atmosphere in a way that is hard to achieve with traditional composition and instrumentation.

Its also worth noting that electronically aided composition that places emphasis on timbre over individual notes devalues musical notation as it is unnecessary for it to be used as either a source of a composition or as a storage medium. As Eno himself states:

> "I think there is a difference in kind between the kind of composition I do and the kind a classical composer does. This is evidenced by the fact that I can neither read nor write music, and I can't play any instruments really well, either. You can't imagine a situation prior to this where anyone like me could have been a composer. It couldn't have happened. How could I do it without tape and without technology?" (Eno, 1983)

Furthermore, Eno recognises that notation is a textural language that, if used in the compositional process, will shape the outcome in a particular way: "[the traditional composer] has to, in fact, use a language that, like all languages, will shape what he wants to do" (Eno, 1983). This statement is consistent with McLuhan's ontology of the post-literate society in which outcomes are mediated by technological means and, in McLuhan's terms, it places Eno's work firmly within the context of the post-literate society, a society that values the aural above the visual senses and thus devalues text in favour of sound. This also places Eno's thought within a cybernetic ontology in which human and machine interact in a dance of agency, which does not require text as a basis for narrative and structure.

The mode of listening Eno requires of the audience also reflects the human, machine, and environment aspect at play within Ambient Music, the recognition that probabilistic sounds that may occur within the environment (sounds that don't emanate from the speakers), combine with the music and figure in the overall listening experience. It also encapsulates the volume at which one may listen to the music, with lower volumes set on a playback system, there will be more blending with the sound world or the environment. In fact Eno makes this aspect explicit: "I suggest listening to the piece at comparatively low levels, even to the extent that it frequently falls below the threshold of audibility" (Eno, 1975).

The final aspect of Ambient Music to explore is not only Eno's desire that the music mingle with the environment, but the capacity of the studio to allow the creation of self-contained sonic landscapes and ecosystems – a 'world within a world', so to speak. The last of the Ambient Album series, *Ambient 4, On Land* (1982) is deliberately nostalgic for real world environments, with tracks such as *Lizard Point, Lantern Marsh, Unfamiliar Wind (Leeks Hills)*, and *Dunwich Beach, Autumn, 1960* all being evocative of real places or memories of real places. Eno describes these pieces of music as being "an attempt to transpose into music something that you can do in painting: creating a figurative environment" (Eno, 1982). He also cites Federico Fellini's 1973 film, *Amarcord* [English title: I Remember] as an influence on the liner notes to the album. However, in discussing Stafford Beer's cybernetic influence on Eno's work and in describing Eno's Ambient music, Andrew Pickering writes: "Beer's ontology of exceedingly complex systems conjures up a lively world, continually capable of generating novel performances. Eno, so to speak, picked up the other end of the stick and focused on building musical worlds that would themselves exhibit unpredictable, emergent becomings" (Pickering, 2011). This not only speaks to Eno's desire to create self-contained musical worlds, but also to the systems Eno employed to create the music, which are indeed generative systems and in a 'closed' system sense may be looked upon as 'worlds within themselves'.

It is also interesting that despite the personal introspection of this album, Eno still deems it necessary in the sleeve notes to describe an alternative technological listening set-up to create a more immersive listening environment. This is a three speaker set-up, which may be realised by wiring the two stereo speakers in the conventional way and then wiring a third speaker to the two positive speaker connections from the amplifier, which is then placed behind the listener. Here, Eno is suggesting a listening environment that is achieved through technological means and therefore the listening experience is mitigated by technology.

6.2.7. Generative Music

Generative music was a term coined by Brian Eno in 1996, which coincided with the release of *Generative Music 1* (SSEYO, 1996). The music was released on floppy disk by the company SSEYO and required their Koan generative music software and a PC with a general MIDI-compatible soundcard for playback. Eno composed a number of pieces of music for this release, which were in essence a set of rules encoded into the software. Each time the software was run it would play differently, but at the same time retain some sonic consistency. While Eno has composed many pieces of music using Koan and it is true to say that this was the first released music by him that was different in each iteration from the audience's perspective, he believes that his work in this area extends back to *Discreet Music* (1975) and is coincident with the inception of Ambient Music in the 1970s (Eno, 1996a). This is true in the sense that many of Eno's works are systems-based and that what is heard on record is only one possibility from many possible iterations – chosen, it is presumed, because its qualities are the most aesthetically pleasing.

6.2.7.a. Generative Music: Influences & *Discreet Music*

Eno cites two pieces of music as having a major influence on his approach to designing musical systems. Firstly, he identifies Terry Riley's *In C* (1964), which consists of 52 bars of music, centered around the Key of C. Each musician is instructed to play each of the bars as many times as they wish and then proceed to the next bar. The complexity arises as each musician proceeds through the piece at their own speed, producing a myriad of unpredictable combinations. Andrew Pickering comments: "Here we find key elements of Eno's own work. The composer sets some initial conditions for musical performance, but leaves the details to be filled in by the dynamics of the performing system" (Pickering, 2011). The second piece that Eno cites as an over-arching influence is Steve Reich's "It's Gonna Rain" (1965). Here we also see complexity achieved from some very simple initial starting conditions. However, in this case it happens via technological means. The piece is made from a tape loop of a preacher saying, "It's gonna rain", which is run simultaneously on two tape machines. The complexity occurs as the two machines slowly go in and out of phase with one another. Eno describes the resulting sonic effects: "Quite soon you start to hearing very exotic details of the recording itself. For instance you are aware after several minutes that there are thousands of trumpets in there… You also become aware that there are birds." (Eno, 1996b). In some senses the combination of these two approaches is the crux of Eno's generative approach: 1) to overlay musical phrases and sounds in a laminar and non-contiguous way, and 2) to enable this to happen through the use of technology.

Discreet Music (1975) was perhaps the pinnacle of Eno's generative musical experimentations with analogue technology; an operational template that he has reused many times in his compositions. The piece utilises the same tape-loop techniques Eno had pioneered 2 years earlier in the making of the album *No Pussyfooting* (1973), which was a collaboration with the guitarist Robert Fripp. In fact, Eno had initially intended to use the recording of *Discreet Music* as a backing track for a live performance with Fripp. But on listening to the recording he realised that it exemplified the new music he had envisioned while lying in bed recovering from his car accident.

The system Eno designed for *Discreet Music* was based around a long tape loop, which allowed sounds to be recorded and layered over each other in a continuous five-second loop. Figure 1 depicts a diagram of the system as shown in the liner notes on the album cover. Here we see sound from a synthesiser (playing a preset arpeggio), which has been routed through a graphic equaliser and an echo unit. The bold black line with arrows represents the transit of the audio signal. The sound then enters the first tape recorder and is recorded onto the tape here via the record head. The tape then runs from here to a playback head to a second tape recorder. The distance between the two recorders introduces a long delay line. The audio output of the second tape recorder is then fed back into the first tape recorder by means of an audio cable. The Revox A77 tape machines used by Eno had two audio inputs. In this set-up the first input (input A) would be from the synthesiser and input B would be the delay return from the second tape recorder, thus mixing the input and the delay line together on a continuous tape loop, in which new inputs are layered on top of old ones.

Fig. 19. The technological set-up for recording the album Discreet Music (Eno, 1975b)

Musical inputs from the synthesiser and effects units are altered in real time in relation to the combined output. The musical effect of this process is both hypnotic and intriguing, as the slowly shifting layers are both repetitive and fluid in the same instance. This effect is surmised in another of Eno's maxims, immortalised on an Oblique Strategies card: "Repetition is a form of change" (Eno and Schmidt, 1975a). However, one of the main musical features of the system, its ability to slowly shift over time, is due to an inherent technological feature of the analogue tape, namely that each layer that passes over the record and playback heads slowly degrades as each successive new layer is recorded onto the tape. This means that after say 15 or 20 passes of the loop through the system, the first recorded layer will have completely degraded and will no longer be audible. This prevents total audio saturation of the loop (an effect that is easy to achieve with a digital configuration of such a feedback system) and thus the musical soundscape shifts over time.

Eno has been keen to point to the importance of the system in the compositional process, citing on a number of occasions that *Discreet Music* was made "almost by accident": after setting the system to play and record he was interrupted by a telephone call and also had to deal with a number of other distractions, meaning that a good deal of the recording was simply the system playing through its permutations. Furthermore, when playing the track to Robert Fripp the next day, he mistakenly played the tape at half speed. On hearing the result, Eno thought "it was probably one of the best things I'd ever done and I didn't even realise I was doing it at the time" (Sheppard, 2008). The liner sleevenotes also point to the importance the system plays in the compositional process: "Since I have always preferred making plans to executing them, I have gravitated towards situations and systems that, once set into operation, could create music with little or no intervention on my part. That is to say, I tend towards the roles of planner and programmer, and then become an audience to the results" (Eno, 1975b).

Here again we see the enacting of a cybernetic ontology, one in which the system (in concordance with Beer's terms) is designed to produce emergent (musical) behaviours, which may be altered in real time to effect the outcome; the dynamics of the system may be ridden in the direction you wish it to go. Furthermore, we see the composer as the author of the work diminished; the composer, technology, environment, and the probabilistic processes at play in all three constitute the non-hierarchical system that produces the music.

6.2.7.b. Generative Music: Eno's Cybernetic Systems Music – Cellular Automata & Koan

In the winter of 1978, Eno took an extended holiday in San Francisco. During his stay there he became obsessed with the Exploratorium, the city's 'hands-on' science museum and in particular with one exhibit known as the *Game of Life*. Designed by Cambridge mathematician John Conway and based on the computational and mathematical work of prominent cyberneticians such as John Von Neumann and Norbert Wiener (among others), Conway designed the first computer simulation of cellular automata. In practice these consisted of squares on a grid that would 'come to life' or 'die' based on a simple set of rules. The game grew from Von Neumann's research on self-replicating machines. However, in action it uncannily replicates biological growth and demonstrates how complex systems can arise from very simple initial conditions. Within the game, one is able to set the starting conditions by using a cursor to draw in 'live' squares on the grid. The game is then run through its generations and if squares are in close proximity to each other they will interact based on the following rules: "1. Any live cell with fewer than two live neighbours dies, as if caused by under-population, 2. Any live cell with two or three live neighbours lives on to the next generation, 3. Any live cell with more than three live neighbours dies, as if by overcrowding, and finally 4. Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction" (Conway, 1970).

Fig. 20. A still image from Conway's Game of Life: http://www.webmonkey.com/2010/07/conways-game-of-life-in-html5/

Depending on initial starting conditions, the game may produce very simple patterns that die out after only a few generations, or it may produce exceedingly complex patterns that resemble bacterial life or complex machines with a variety of behaviours. According to Eno, the Game of Life is "one of the great experiments of the twentieth century [...] like the Beatles in science" (BBC, "Arena", 2010). According to Eno Biographer, David Shepard, Eno spent whole days playing with the exhibit, becoming an unofficial guide to the programme for visiting tourists (Sheppard, 2008). In later reflection on his time spent with 'Life', Eno stated: "I wanted to train my intuition to grasp this. I wanted this to become intuitive to me. I wanted to be able to understand this message that I'd found in the Steve Reich piece, in the Riley piece, in my own work, and now in this. Very, very simple rules, clustering together, can produce very complex and actually rather beautiful results. I wanted to do that because it felt that this was the most important new idea of the time" (Eno, 1996b).

While Eno immediately saw a parallel between the Game of Life and his own and his contemporaries' musical practice – set starting conditions, run the system and see what happens – it also pointed to a new way of configuring heuristic systems using computers. The Game of Life demonstrated that, with some adaptations, a similar computer program could provide a mechanism that would allow the 'planting' of musical 'seeds' (musical notes or sounds) that, given the right conditions, would 'grow' (organically sequence) a piece of music. For Eno, this organic metaphor is an important defining aspect of his generative compositional process:

> "Generative Music is like trying to create a seed, as opposed to classical composition which is like trying to engineer a tree… I think one of the changes of our consciousness of how things come into being, of how things are made and how they work is the change from an engineering paradigm, which is to say a design paradigm, to a biological paradigm, which is an evolutionary one. In lots of areas now, people say, 'How do you create the conditions at the bottom to allow the growth of the things you want to happen?' So a lot of the generative music thing is much more like gardening. When you make a garden of course you choose some of the things you put in, and of course you have some degree of control over what the thing will be like, but you never know precisely. That's the wonderful thing about gardening. It responds to conditions during its growth and it changes and it's different every year" (Toop, 2004).

It would be a number of years before Eno would be able to utilise a software package that would allow him to create music in the way he had envisioned from his experience with the Game of Life. In Early 1995 Eno received a CD of music that was made using the generative music software program called Koan. The pieces had been composed in *his* style and he was struck not only by how similar they were to his work, but also by how good they were. He contacted Tim Cole at SSEYO who designed the software and asked if he might have a copy of the program (Eno, 1996a). Koan is essentially a MIDI sequencing package that allows for non-linear rules to be applied to the sequence. Eno explains that the software enables "a composer to control about 150 parameters that specify things like sound-timbre and envelope, scale, harmony, rhythm, tempo, vibrato, pitch range, etc. Most of Koan's instructions are probabilistic – so that rather than saying 'Do precisely this' (which is what a musical sequencer does), they say, 'Choose what to do from within this range of possibilities'" (Eno, 1996a). Thus musical works can be composed that utilise the same sound set and have a constancy in musical output, but are different in each iteration: no two pieces of music will be the same, but each will bear the hallmarks of a composer's style. In other words, each is different but each adheres to a class of goals, a characteristic that shares a similarity with biological life.

While Eno is very technically adept with the Koan software and has used it to produce many of his recorded generative works and sound installations since the mid-90s, he insists that the technicality of the systems he employs to make music is not an important component in the music-making process; the fact that the music is mitigated by technology is important, the cybernetic axis of human, machine and environment is crucial to his ability to make music. However, the inner workings of those systems are not important. As long as the system is capable of approaching music creation in a new way, how it achieves this is not a concern to Eno:

> "In a way the mathematics is not the interesting part for me, the interesting part is how you rethink how something is made, how something comes into being. Even with the composers you mention [Xenakis], they were quite classical composers because in the end they wrote it all out; in a sense they described it in advance. Now there were other people like Cornelius Cardew, John Cage, Christian Wolff who were doing something more interesting, they were inventing systems which produced music. Now, that's a total break from the Western classical idea. The idea is that your job as composer is to design a machine or system which you can provide inputs to and which will output music. So you forgo the thing that composers usually do which is to design music in detail, so that you're no longer exactly the architect of a piece of work but more the designer of a musical ecosystem. You put a few things in place and see how they react or what they do to each other" (Eno in Whittaker, 2003).

In summing up this section on Eno's generative music, it is worth highlighting two sentences from the above quotations: "I think one of the changes of our consciousness [is] of how things come into *being*" (Toop, 2004), and "the interesting part is how you rethink how something is made, how something comes into *being*" (Whittaker 2003). Both these statements demonstrate a concern with emergence and becoming, which are central themes in cybernetics. However, they also demonstrate a concern with *being* in the Heideggerian sense, and particularly in relation to Heidegger's essay "The Question Concerning Technology" (1954). In this context we may see Eno's work as a recognition of the enframing nature of technology and that subversive participation in the technological milieu may reveal glimpses of the true nature of Being (Heidegger, 1954).

While it is very doubtful that Eno is aware of this philosophy, his concern with *being* in relation to generative music demonstrates that the ontological position of his work takes precedence over epistemology. He is also attempting to be radical in his approach to using technology, to break free of Western classical traditions. Both these perspectives align with Heidegger's philosophy, which in turn aligns with many cybernetic precepts.

6.2.7.c. Meaning and aesthetics in generative music

Generative music represents a break with Western music's hierarchical tradition, in which the lone composer disseminates his artistic vision and imbues the piece of music with meaning to players and audience. In Eno's generative compositions, he is working to a set of beliefs and influences that hold to an ontological position, in which cybernetics plays a significant role, and meaning may be discerned by an audience as an emergent property of the composition, not as something prescribed by the composer. This lack of imbued meaning through direct authorship is further alluded to by Eno himself: "With this Generative Music… am I the composer? Are you if you buy the system the composer? Is Jim Coles and his brother who wrote the software the composer? Who actually composes music like this? Can you describe it as a composition exactly when you don't know what it's going to be?" (Eno, 1996b)

Eno's generative and ambient music has a distinct musical quality: soft tones, sparseness, quietness, mingling with the environment, evolving loops, oblique melodies that never appear to coalesce, and music that is said to be calming and beautiful. Inevitably, this style may invoke a response in the listener, perhaps of contemplation, relaxation, meditation, and so on. However, while Eno is often quoted as saying that he likes the state of "surrender" that certain music engenders, this is not the full story behind the artistic and aesthetic impetus behind this music. Eno states:

> "All of the encouragement of modern life is to tell you to pay attention to yourself and take control of things. We can invent technologies and we can think of ways of organising the world to our advantage, to our benefit. However, the other thing we obviously love doing is almost completely the opposite, it's putting ourselves in situations where we're not the primary figure, where we are not in control, we're carried along, we're floating on something. And I like that state that I call surrender and other people call transcendence, and other people call getting out of it (*laughs*)" (BBC, Arena, 2010).

It would seem from this statement that Eno is only advocating 'surrender' in the musical experience, however, one of his often quoted statements is "For the world to be interesting you have to be manipulating it all the time" (Bangs, 1979). Furthermore, his interactive iPhone and iPad music apps such as Bloom and Scape suggest a more complex relationship with music than merely surrender. Perhaps the soundscapes Eno creates may engender surrender, but within this there is also the capacity to manipulate and change the musical environment if desired – even an action as simple as turning down the volume is something that Eno see as an important consideration (Eno, 1975b). It would appear that the above statements concerning ‘control’ and ‘surrender’ are a recognition of this axis within music, a sliding scale in which control and surrender exist at polar extremes and the measure of a composition’s effect will exist at some point on this scale. And most significantly, it is an axis that is concerned with states of *being*, as opposed to emotions.

Other qualities of Eno’s music include its seductiveness, its unpredictability, and its constant subtle manipulations of timbre, which mean that his music bears close listening as well as merely providing a background. Eric Tamm, for example, considers manipulation of timbre to be the defining aspect of Eno’s compositions (Tamm, 1995). While timbre manipulation is an important aspect of Eno’s style, it is only made possible by the technologies he employs (predominantly EQ and filtering). By Eno’s own admission, technology is what makes it possible for him to compose music in the first place. It is reasonable to assume, therefore, that his distinct use of these technologies in totality (not just the use of filters and EQ) in a human/machine/environment paradigm, supersedes timbre composition as the primary defining aspect of Eno’s compositional style.

Beauty and mystery are also notable characteristics often attributed to Eno’s music (BBC “Arena”, 2010). As we have seen, the English new music’s “cult of the beautiful” was a strong influence on Eno’s work but it would appear that these attributes also have influences of a more personal nature. As a small boy Eno developed a love of the doo-wop music played on jukeboxes by the American Air Force personnel who were stationed near his hometown. The young Eno had no point of reference for this music, which he recalls as being quite unlike anything one would hear on the BBC at the time (BBC “Arena”, 2010). He found it to be “alien and totally other” (Tamm, 1995), and describes “always being impressed by music that I couldn't penetrate the mystery of” (BBC *Arena*, 2010). This experience combined with his recurrent singing of the Catholic mass in Latin as a child, a language he did not understand and experienced as “singing as pure sound” (BBC *Arena*, 2010), were both early formative musical encounters for Eno. The music critic Paul Morley points to the mystery and beauty of Eno’s music as having religious overtones, even for secular listeners (BBC “Arena”, 2010). This religious overtone stems from Eno’s prime choice of instrumentation, which often features choir, organs, and bell sounds, all of which are associated with the church. Furthermore, Eno employs ‘black box’ systems to organise these sounds (Koan, for example, or unsynchronised tape loops), whose complexity and unpredictability of organisation, a characteristic shared with many organic systems, makes them impossible to penetrate by empirical observation (the flow of water in a stream, for example). Again, we also see a concern with *being*; an encounter with the musical *other* is primarily a state of being, not a definable emotion.

Another aspect of Eno’s conceptual thinking is his interest in metaphor. However, this is not in the sense of an artistic device in his work, rather that he considers it as a form of modus operandi: “Evolving metaphors, in my opinion, is what artists do. They produce work that gives you the chance to experience in a safe environment, because nothing really happens to you when you are looking at artwork, they give you the chance to experience what might be quite dangerous and radical new ideas. They give you a chance to step out of real life into simulator life. A metaphor is a way of explaining something that we've experienced in a set of terms, a different set of terms" (Eno, 1996b). Eno takes the example of the metaphor for an argument, which is that of "war". If this metaphor of war was shifted to one of dance, an entirely different discourse might be possible (Eno, 1996b). The ideas Eno exposes above, in particular of art creating a safe space in which to play out scenarios, are directly taken from Morse Peckham's thesis in *Man's Rage for Chaos* (Peckham, 1967). However, Eno's musings on metaphor in this context suggests a different emphasis, one that can change the state of the artist's practice and present new ways of thinking and being. The cybernetician Gordon Pask defined cybernetics as: "the science or the art of manipulating defensible metaphors; showing how they may be constructed and what can be inferred as a result of their existence" (Pask, 1966). While its unclear if Eno was aware of this definition (although he was very familiar with the *Cybernetic Serendipity* exhibition at the ICA, in 1966, at which Pask and Roy Ascott both exhibited), it illustrates how closely related Pask's view of the practice of cybernetics and Eno's ideas of the practice of the artist were in relation to employing metaphor.

Returning to the theme of meaning, Eno strongly takes Ascott's line, that the meaning of a work of art is created in the mind of the audience as they experience it: "Music is actually a contingent combination of sounds whose emotional resonances are entirely dependent on the audience's personal and shared histories as listeners" (Eno, 1996b). Furthermore, that meaning is also contingent on the "frame" or context of the artwork:

> "One of the interesting things about generative systems is that they depend a lot on the observer as well, so one of the things that a lot of my work counts on is that if you put something on a CD, people will tend to think its probably music (laughter)… but it's funny, if you put something in a frame and put it in an art gallery, people will think it's a painting and they'll reserve a special kind of attention for that… Something I'm very aware of is that people tend to connect things together in their brains, a lot of my work involves using light and sound together and I never synchronise them but people always think that they're synchronised" (Eno, 2006).

The frame and context also includes the environment. The inclusion of the environment places the listener in a real space and time; the immersive experience of Eno's music requires immersion in a real environment. Furthermore, the organic nature of the structure of the music reflects the (probabilistic) real soundscape within which it is situated. These aspects further emphasise *being*, as it requires the listener to be aware of the environment that he or she exists within, and of his or her relationship to it and the music.

The question of meaning in generative music is most prevalent when one considers Eno's fundamental ontological position, which is one of becoming, emergence, and self making; an understanding that certain systems (particularly biological ones) are able to create order from chaos; and that given some very small inputs, complex systems may emerge. From the cybernetic, constructivist standpoint, meaning is only formed through action and interaction, there is no intrinsic meaning in things; meaning emerges through interaction.

6.2.8. Conclusion

This writing on Eno's work began by highlighting four aspects of Eno's compositional process that relate to ontology: 1) the de-emphasis of the composer; 2) the recognition and use of probabilistic processes in composition; 3) the de-emphasis of musical notes in favour of timbral composition; and 4) the role asked of the listener. We have seen how each of these positions has been made possible or mitigated by technology and how these aspects relate to Marshal McLuhan's post-literate society theory, in which the "medium is the message", and Heiddeger's radical participation in technology that may reveal true 'being'.

Each of the four perspectives above relates strongly to the cybernetic ontology of Emergence and Becoming, and the cybernetic precepts of "order from noise" (Wiener, 1948); "non-hierarchical organisation" (Beer, 1972); "black box", performative ontology (Ashby, 1956); and the human/machine/environment paradigm (Wiener, 1948). Eno's cybernetic art-school training and his early encounter with Stafford Beer's work informed his approach to music-making from the beginning of Roxy Music, through Ambient Music, and culminating in his current work with Generative Music. Furthermore, the role he played in the new English music movement of the 1960s and 1970s helped him to further formulate a compositional approach and aesthetic. Through his examination of Cardew's work in a cybernetic context, he further cemented an idea of what cybernetic composition might sound like in practice.

Eno seeks to define his own compositional path and is suspicious of aligning himself wholeheartedly to any musical style or genre, preferring to create his own stylistic niches. While process-driven and systems-driven music lies at the conceptual heart of his approach, he is keen to assert his own aesthetic sensibilities: he will always intervene if the result of his musical system does not match the "beautiful" aesthetic. On this topic, he muses: "I wanted the Staffordian approach to do two things: to pitch me into aesthetic areas beyond where my taste would normally take me. That's one of the things you find working with systems, that they throw up configurations that you couldn't have thought of. I wanted the system to confront me with novelty; but I did also want to say, 'I prefer this part of it to that part, this part doesn't make sense, that part does.' […] The systemic approach […] is certainly very good at imagination expanding" (Whittaker, 2003).

When meaning is considered in relation to Eno's generative music it reveals a preoccupation with being as it relates to the creation of the music and the situation of the listener. The ontology that Eno adheres to is a cybernetic one – one that concerns emergence and becoming, but also adheres to Heidegger's conception of revealing 'being' by participating in technology in a radical way. Eno is not interested in using technology in a conventional way, but rather in a way that concerns radical (when compared to other musical traditions) implementations for creating music.

Eno's influence on popular music is extensive. Through his work as a producer and artistic collaborator with artists such as David Bowie, Talking Heads, U2, and Coldplay, he has helped to shape the landscape of popular music for the last forty years and gained a reputation as an "experimental electronic producer-composer with a pop audience" (Moorefield, 2005). However, perhaps more important than the sound of these records, it is the working practices he has employed with these artists that have gained him a reputation as a pioneer. These have involved his use of the Oblique Strategy cards with David Bowie and his use of non-hierarchical, 'network composition' techniques with David Byrne and Talking Heads (Sheppard, 2008*)*. Eno creates metaphors and systems that artists can use to expand their creative possibilities. Here again we see cybernetic methods employed to shift perspectives and modes of being within the creative process. Furthermore, Eno's use of systems in his music making has brought the focus and attention of a wider popular music audience to experimental music and the creative possibilities that cybernetics in music has to offer.

6.3 Agostino Di Scipio & Iannis Xenakis

This approach, by which one invents and works out interdependencies among real-time control variables, already reflects a paradigm shift from interactive composing (as in the pioneering work of Joel Chadabe and other composers, in the 1970s) to composing interactions. In my view, the shift is especially relevant when composed interactions are audibly experienced as a music of sound (timbre composition), more than a music of notes (as is often the case with interactive music systems, especially when instrumentalists are involved) (Di Scipio, 2003).

Born in 1962, Agostino Di Scipio is perhaps the most prolific and best known contemporary composer and theoretician to utilise cybernetics and systems theory in the creation of his musical works. Born in Naples, Italy in 1962, he had a burgeoning interest in music in his teenage years, firstly as a self-taught musician and later with electronics and computer programming. He also developed an interest in experimental theatre whilst studying at the Istituto Universitario Orientale, in Naples (Di Scipio, A. 2014). He later studied Composition and Electronic Music at the Conservatory of L'Aquila, where his teachers included Michelangelo Lupone, Giancarlo Bizzi, and Mauro Cardi. During this time he studied Computer Music at the Centro di Sonologia Computazionale, University of Padova (Di Scipio, 2014).

He has been a guest composer at a number of prestigious institutions including CSC in Padova (1987–1991), ZKM (Karlsruhe, 2005–06), IMEB (Bourges 2003 and 2005), and artist-in-residence for the DAAD Künstlerprogramm in Berlin (2004 and 2005). He has held the position of lecturer in live-electronics composition at CCMIX in Paris (2001–2007) and has been Professor of Electronic Music at the Conservatory of Naples (2001–2013), and currently holds the same position in L'Aquila. In the winter of 2007/8, he served as Edgar Varèse Professor at the Technische Universität in Berlin (Di Scipio, 2014). He has also been a guest professor at a number of notable academic institutions, including the University of Illinois, Urbana-Champaign (2004), University of Paris 8 (2013), IRCAM (2013), Johannes Gutenberg Universität (Mainz, 2004), Simon Fraser University (Burnaby-Vancouver, 1993) and the Sibelius Academy (Helsinki, 1995). He also delivered the opening keynote speech at the International Computer Music Conference 2013, in Perth, Australia (Di Scipio, 2014).

By his own admission, his research in the area of sound and music is "unconventional" (Di Scipio, A. 2011), and yet his notoriety and academic stature demonstrate that the ideas he explores in his works speak to important social, political, and cultural themes prevalent in modern times, namely those of complexity, the coupling of human, machine and environment, and emergent structures – all of which are strong themes either within, or born from, cybernetics. Di Scipio's interest in cybernetics and emergent behaviours stems from his initial concern with interactive computer music and (granular) micro-sonorities, as expounded by Iannis Xenakis.

Di Scipio recounts his creative journey: "I had a very early phase when I gathered as much knowledge as possible about computer music techniques and digital signal processing. […] In retrospect, I view that time as one of broad explorations in sonic materials, which eventually took me, later on, to focus on granular, textural and noisy materials… in short, to micro-composition, i.e. to focus on the finest temporal scales in sound – with various degrees of densities and consistencies among sonic grains or particles. The idea was that micro-composition would let macro-level, gestural properties *emerge* at larger time scales. I tried to determine a process in sound in a way that lower-level processes would bring forth larger sonic gestures" (Di Scipio in Placidi, 2010). In the early 1990s Di Scipio also became interested in non-linear dynamic systems of the kind typically associated with chaos theory and sought to implement these ideas as synthesis techniques that could be employed in his compositions (Placidi, 2010).

De Scipio sought to formally investigate these two areas (granular synthesis and dynamic systems) in studying the work of Iannis Xenakis (1922–2001). In his influential work, *Formalized music: Thought and Mathematics in Composition* (1963), Xenakis outlines his 'granular hypothesis', in which he states, "all sound is an integration of grains, of elementary sonic particles, of sonic quanta" (Xenakis, 1963). He further postulates that it is possible to make any existing sound or timbre (as well those as yet unimagined) by combining grains in specific arrangements. This was a formidable supposition as it significantly predated the sampling and DSP technologies that would enable a constructive practical investigation of his theory. As a reaction against the complexity of serialism, Xenakis also postulated a move away from 'linearity' in musical composition. From these insights he developed the notion of using probability in music, formulating what he called "Markovian Stochastic Music" (Xenakis, 1963). Although the introduction of stochastic processes into musical composition was nothing new in the early sixties (Cage, among others, had been experimenting in this area for some time), Xenakis' particular mathematical brand of probability manipulation was inspired by cybernetics. Particularly in his attempt to "generalize the study of musical composition with the aid of stochastics" (Xenakis, 1963), he utilised methodology found in W. Ross Ashby's 1956 book, *Introduction to Cybernetics* (Kollias, 2008). From this extrapolation of Ashby's work, he further postulated that "second order sonorities" would emerge from the interactions of sonic grains; the idea that the interactions of grains over time in the compositional process, at a 'micro level', would form timbres and compositional gestures at the 'macro level' (i.e. the grains, when combined in a certain way, would exhibit emergent behaviours). Xenakis first implemented his granular compositional technique in *Analogique A* (1958) *for string ensemble* and *Analogique B* (1958–59) *for tape.*

Xenakis' granular theory shares parallels with the cybernetic 'order from noise' principle, first formulated by the cybernetician Heinz von Foerster in 1960, which demonstrates that noise facilitates self-organisation by allowing a system to experience a variety of states (in its state space) and increasing the likelihood that the system will tend toward a state of equilibrium (Von Foerster, 1960), which would be observed as emergent phenomena. In describing self-organising systems, the cybernetician Jeffery Goldstein writes, "emergent phenomena are conceptualized as occurring on the macro level, in contrast to the micro-level components and processes out of which they arise" (Goldstein, 1999).

It is certain that Xenakis was reading Ashby's book and considering cybernetics more generally in the early sixties and it is highly likely that he would have come across Von Foerster's theory or made the logical leap from reading Ashby's work when formulating his theory of 'second order sonorities'. While *An Introduction to Cybernetics (*Ashby, 1956) is not specifically about self-organisation (of the 'order from noise' variety), it does, however, examine the mathematical principles of a system controlling complex behaviour. The book is also based (in part) on Ashby's prior work on self-organising systems (Ashby, 1947), which laid the groundwork for others, including Von Foerster.

However, Di Scipio is critical of Xenakis' 'second order sonorities'. In his 1997 paper, "The Problem of 2nd-order Sonorities in Xenakis' Electroacoustic Music", and again in his 2001 paper, "Clarification on Xenakis: The Cybernetics of Stochastic music", Di Scipio attacks the notion that Xenakis' granular, stochastic compositional method produces second-order sonorities: "one may ask whether the stochastic does really provide as good a means for higher-order sonorities to emerge from a ground-level pattern of minimal sonic units […] just as the pizzicatos of *Analogique A* could not but remain string pizzicatos, however dense their articulation, the electronic grains in *Analogique B* remain just grains and do not build up into a more global auditory image" (Di Scipio, 2001). Furthermore, Di Scipio criticises the pieces from a cybernetic perspective, stating, "although the mechanism (system) is sensitive to initial conditions it is unable to be influenced by the events of its own function. Instead, only the composer is capable of influencing the mechanism from the outside" (Kollias, 2008). Di Scipio recognises that it is also a "closed system" (Di Scipio, 2001) and is therefore not able to produce second-order sonorities, as it does not appropriately adhere to the 'order from noise' principle, or any other cybernetic self-organisation theory. In order to develop a system capable of second-order sonorities, Di Scipio asserts that a more advanced systemic notion is required, that of the self-organising system (Kollias, 2011). This necessitates an ontological shift in approach, one that recognises that any dynamic system is situated within an environment and is reactive to environmental conditions. Di Scipio also recognises that self-organising systems require a more self-reflexive design ethos, as opposed to the closed-system approach utilised by Xenakis. Di Scipio's criticism of Xenakis' approach neatly reflects some important differences between first-order and second-order cybernetics and distinguishes Di Scipio's investigation as being distinctly of the second-order variety.

Consideration of this second-order cybernetic design ethos brings us to another important pillar of Di Scipio's research, namely the question surrounding interactivity – or more precisely, interactive music systems and his alternative strategy in this area. In his 2003 paper, "Sound is the interface: from interactive to ecosystemic signal processing", Di Scipio criticises the linear approach taken in the design of interactive music systems: "a linear design ontology is taken as if it were the only one we may think of when speaking of such things as 'live electronics' and 'interactive music'" (Di Scipio, 2003). He further asserts that almost the entire multitude of devices and computer protocols utilised in interactive music systems adhere to a linear communication flow, as depicted in Figure 21 (below).

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Fig. 21. Basic design in interactive Music Systems (Di Scipio, 2003)

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Fig. 22. Implicit feedback loop in interactive system design (Di Scipio, 2003)

While there is an implicit feedback loop in this arrangement, as illustrated in figure 21, Di Scipio argues that this is limited and seldom considered: "this recursive element is a source of creative developments, yet it remains purely optional (note the dashed arrow in figure 22, above), as the basic communication flow is a linear one" (Di Scipio, 2003). He further asserts that the underlying ontology is one where the *agent acts* and the *computer re-acts*. In this system he postulates that, "for the proper reaction to take place, in principle there should be no noise in the external conditions, no unwanted or unforeseen actions on the agent's part" (Di Scipio, 2003). In the common notion of interactivity, the agent/performer is the only source of energy for change in the system and the only agent capable of assessing the external and internal state of the system and of the music being produced and played into the environment. Di Scipio argues that this common view ignores the fact that the agent/performer is only a component in the overall meta-system, which incorporates man, machine, and environment.

The approach that Di Scipio proposes here, one that encompasses the environment in the human/machine interaction, and allows for the possibility of feedback from the environment, is central to the cybernetic ontology. In fact he makes the cybernetic approach explicit in the introduction to his paper: "I try to answer [the question of interactivity] by adopting a system-theory view, more precisely a *radical constructivistic* view (Von Glasersfeld 1999, Riegler 2000) as found in the cybernetics of living systems (Maturana and Varela 1980) as well as social systems and ecosystems (Morin 1977)" (Di Scipio, 2003). With this paradigm in mind, Di Scipio approaches the question of interactivity from an ecological viewpoint:

> "The very process of 'interaction' is today rarely understood and implemented for what it seems to be in living organisms (either human or not, e.g. animal or social), namely as a *by-product of lower level interdependencies among system components*. In a different approach, a principal aim would be to create a *dynamical system* exhibiting an adaptive behavior to the surrounding external conditions, and capable to interfere with the external conditions themselves [sic]" (Di Scipio, 2003).

He further states that the system should be capable of being a "self-observing system" (Di Scipio, 2003) – independent from an agent/performer – and capable of tracking what happens both externally and internally and making adjustments accordingly. He cites Gordon Mumma's *Hornpipe* (1967) as a pioneering example of such a system (Di Scipio, 2003). Here, interaction is no longer a case of '*agent acts, computer re-acts*', as in the linear model. Instead, it becomes a fundamental structural element from which emergent properties may arise. The flow of energy in the system is no longer one-way (i.e. from the composer); energy may be derived from the environment and a composition may be self-sustaining, with little real-time input from a composer/performer. It becomes obvious that in such a system the design of the interactions, between all the components of the system, are fundamental to the construction of the composition; without a considered, ecosystemic design, interactions will simply not occur. He states: "I think that these interrelationships (between elements of a system) may, instead, be the object of design, and hence worked out creatively as a substantial part of the compositional process" (Di Scipio, 2003).

Di Scipio sees this as an important shift in emphasis, from the dominant approach of *interactive composing* to one of *composing interactions.* Here the composer does not compose the musical result but instead the interactions that create the music. He views this shift as one that moves away from "creating wanted sounds via interactive means, towards creating wanted interactions having audible traces. In the latter case, one designs, implements and maintains a network of connected components whose emergent behavior in sound one calls music" (Di Scipio, 2003). Furthermore, he sees this shift as being one that is particularly relevant "when composed interactions are audibly experienced as a music of *sound*" (Di Scipio, 2003), which he calls 'timbre composition' as opposed to a music of *notes*, which he sees as being particularly prevalent in interactive music, especially where instrumentalists are involved.

This is an important distinction as it sees the setting aside of the necessity for notation in eco-systemic composition. Concentrating on the composition of interactions at a micro level negates the need for notation at an intermediate level (prior to the macro, perceived-sound level). This view of the redundancy of notation is concurrent with pragmatic philosophy's view of the redundancy of text in the modern electronic age. McLuhan and Dewey believed that since the invention of the telegraph, text has assumed a subservient role to aural/acoustic forms of communication. McLuhan asserted that this elevation of the aural/acoustic was akin to an ontology that existed in a pre-literate phase in human history (Coyne, 1995). We may see that the history of musical notation has followed a concurrent path to that of written text, from its non-use in pre-literate societies to its hegemony in the (western) literate society, and to its non-necessity in the post-literate/electronic age.

The negation of notation is a common practice in modern improvisational forms and electronic musical composition, and particularly in compositions that utilise cybernetic processes, where (to paraphrase McLuhan) the medium *is* the music (or more precisely, but with less alliteration, the medium *is* the sound). Di Scipio conjures the spirit of this notion in his term "sound is the interface" (Di Scipio, 2003), which he uses as a meta-descriptor for his compositional approach.

The non-necessity of text, notation, and symbols in the making of meaning also resonates with modern debates surrounding the modelling of cognition. In writing about Di Scipio's music, Renaud Meric and Makis Solomos consider this parallel:

> "The idea of emergent sound structures is related to the elaboration of *sub-symbolic* theory. In the 'theory of sonological emergence', the emergence of a high level should happen through grains and samples, neither of which are symbols as they are located on a low level (Di Scipio, 1994). With composed interactions[23] (Di Scipio puts the interaction at the signal level: all the information exchanges have a sonic nature (Di Scipio, 2003). We can draw a parallel between this strategy and the model of emergence in cognitive science. To the question, 'What is cognition?' the 'computationalist' model answers: 'data processing: the manipulation of symbols from rules' (Varela, 1996), while the 'emergence' model answers: 'the emergence of global states in a network of simple components' (Varela, 1996). As regards music, the issue at stake here is as follows: if we want the higher level (the macroform) to appear as an emergence and not as an independent construction, we have to work only at the lower level, abandoning the intermediate level, which is the level of symbols" (Meric, R. and Solomos, M., 2009).

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Fig.23. Triangular recursive ecosystemic connection (Di Scipio, 2003).

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Fig. 24. Basic design of the Audible Eco-Systemic Interface (Di Scipio, 2003).

[23] We may also find a prime example of such 'composed interactions' in Roland Kayn's work in section 5.5 in this thesis.

Di Scipio's most radical assertion in his ecosystemic model is perhaps that the need for human intervention in performance is irrelevant. He prefers a machine/environment interrelationship (as opposed to the cybernetic human/ machine/environment interrelationship), whereby functions of the noise in the environment (for example amplitude or frequency parameters) regulate the internal functioning of the DSP processes (Di Scipio, 2003). However, as we can see in Figure 23, in the triangular recursive ecosystemic model, human interaction in performance is distinguished as being optional by the dotted line. In performance implementation, Di Scipio favours the interaction of human agents only as actors within the sonic environment, or as the initial composer of the interactions (prior to performance), no human agent interacts directly with the computer interface during real-time signal processing in the performance.

In the eco-systemic compositional paradigm, Di Scipio also sees the role of ambience and noise as being essential to the process of music creation. In the linear model of interactive music systems, noise is something to be eliminated, but in the self-organising system (and in this case specifically Di Scipio's conception of interactive music), "noise is a necessary element, crucial for a coherent but flexible and dynamical behavior to emerge" (Di Scipio, 2003). He sees noise as the medium in which the sound-generating system is situated. Noise is also the energy supply; it drives the process by which the system can maintain itself and develop. Indeed, the system cannot exist separately from the environment it inhabits. Of his sonic ecosystems, De Scipio writes: "They are *autonomous* (i.e. literally, self-regulating) as their process reflects their own peculiar internal structure. Yet they cannot be isolated from the external world, and cannot achieve their own autonomous function except in close conjunction with a source of information (or energy). To isolate them is to kill them" (Di Scipio, 2003). He further writes that although it is a paradoxical superstition, in this case, without *context* there can be no *text*. This idea of systemic 'death' shares parallels to Louis and Bebe Barron's conception of their compositional process, in that their circuits 'lived' and 'died' during the act of composition, which reveals how there has been a common conception of cybernetic composition as an organic process from the time of its inception to the present day.

Di Scipio has composed many works that adhere to the cybernetic paradigm. These range from more traditional works that (paradoxically) utilise notation, musical instruments, and performers, to 'self-sustaining' eco-systemic sound installations. Certainly, his work in recent years has seen a shift toward ecosystemic composition and away from more traditional compositional modes. This work has become well known, particularly in the circles of computer music and live electronics (Solomos, 2014). In the early 2000s, Di Scipio began work on the *Audible Ecosystemic Interface* project (AESI). Initially this was not a formalised model but an experimental practical implementation designed to allow him to discover the sonic possibilities of the system. The work later evolved into live electronics solos, such as *Audible EcoSystemics no.1 (impulse response study)* (2002), and *Audible EcoSystemics no.2 (feedback study) (2003)*. The AESI has also been adapted and modified for sonic installations such as *Condotte Pubbliche* (2011). His ecosystemic process was more formally espoused in a number of academic papers, most notably the aforementioned work from 2003 entitled "Sound is the interface: from interactive to ecosystemic signal processing" (Di Scipio, 2003).

In terms of his ecosystemic sound installations (those created after 2003), Di Scipio describes the design as such:

> "The basic idea reflects a self-feeding loop design (figure 24). A chain of causes and effects is established, ideally without any human intervention but the practical instalment and set-up of everything needed for the performance to take place (loudspeakers, electret condenser microphones, a programmable DSP-based workstation, and a mixer console). A compact description of the overall process is as follows. (i) The computer emits some initial sound (either synthetic or sampled), heard through the loudspeakers; (ii) this is also fed back to the computer by two or more microphones scattered around the room (their placement is crucial); (iii) the computer analyses the microphone signals and extracts information on relevant sonic features; (iv) the extracted data is used to generate low-rate control signals and drive the audio signal processing parameters (DSP modules I often use here include granulators and sample playback modules); submitted to audio signal processing is the computer-generated sound itself that was initially emitted; (v) meanwhile, the microphone signals are matched against the original synthetic or sampled signal, and the difference-signal is calculated (the difference in numerical values between original and ambience sound signal, reflecting the room resonances added); (vi) the difference signal is used to adapt a number of signal processing parameters to the room characteristics (the adaptation process takes a variable time-span to complete)" (Di Scipio, 2003).

In some senses Di Scipio's design ethos is very simple: set up a microphone, speakers and computer in an environmental space and wire them in such a way as to create a feedback loop. Then use measurements of audio parameters of the input signal to control digital manipulations of the output sound and round the signal goes until a rich sonic environment is created. As Di Scipio states: "The room resonances affect the parameters in the DSP methods implemented, and the DSP output affects the total sound in the room, generating new sonic material as a function of the resonances themselves" (Di Scipio, 2003). However, understanding of the system becomes complex when considering how audio and control signals are coupled together. Di Scipio is keen to attest that this design is cybernetic, more specifically that it is a bio-cybernetic, 'recursive coupling' – using terms formulated by Von Foerster (1960) – and furthermore, that because of its recursive nature, his system is consistent with the mathematics of chaotic systems (Di Scipio, 2003). In practical implementation this means that changes in the nature of the audio input create changes in how the control data manipulates the audio input, which in turn alters the audio output to the environment, which in turn effects the audio input, and so on. Each element of the system is coupled together in such a way that changes in one time-based iterative element affects all the others, and thus no one element in the system is in overall control; control is achieved as a balance of these elements. It is important to point out that the control data is also not *in control*; should a non-linear dynamic enter the audio input this will also be reflected by a non-linear change in the control data.[24]

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[24] See pages 34–36 of Chapter 4 of this thesis for a mathematical description of this type of recursive coupling.

However, in terms of analysing the compositional ethos behind such a design, the choices made in what control data is utilised, what DSP manipulations are performed, and how the system is coupled together are crucial elements. As Di Scipio states, the interactions are a "substantial part of the compositional process" (Di Scipio, 2003). To examine this in more detail, the DSP elements utilised equate to functions that control, shape and sustain the audio output. These include functions that: 1) compensate (reduce the amplitude of audio inputs); 2) follow (copy the value of a given value, sometimes with a time delay); 3) control redundancy (to increase the number of grains output, thereby increasing the intensity of the overall sound); and 4) control concurrency (support a contrasting sonic feature, e.g. boost low frequencies when high frequencies are prominent) (Di Scipio, 2003). These functions are primarily achieved via granular processing, which is consistent with Di Scipio's, Xenakis-inspired granular approach. These reducing, mirroring, amplifying and complementing functions are also highly consistent with cybernetic ideas of homeostasis and autopoiesis in that they are regulatory functions designed to control entropy in a feedback process. However, it is in describing how these regulatory DSP functions are controlled, specifically by control data, that explanations become more murky, both technologically and in terms of design ethos. What we already know from Di Scipio's description is that control data is derived from measurements of facets of the incoming audio and that these control signals regulate the functioning of the DSP elements, a model that is again entirely consistent with a cybernetic paradigm. Di Scipio states that he uses several measurements of input audio to drive the control data: amplitude, density of events (rate of onset transients), brilliance (or other unspecified spectral properties), and the transient delay between the two recording microphones, in order to track spatial cues of audio in the environment (Di Scipio, 2003). Each of these control elements is subjected to a number of time-variable parameters, such as delays and time-reverse functions. This control data is then mapped onto the DSP functioning. Di Scipio prefers a matrix approach, where one control feature might map onto several DSP processes, or vice versa. He gives this example to illustrate the mapping: "Imagine, in a simplest example, the occurrence of comparatively 'dark' spectra in the ambience sound causing (i) an amplitude decrease in lower frequency bands and (ii), at the same time, by complementing the numerical value for that variable, a shortening of grain durations (shorter grain durations having the effect of a high-pass filter)" (Di Scipio, 2003). Thus the complex self-reflexive design of the ecosystemic compositional system is implemented.

The environmental coupling described above allows for a self-reflexive system, one that is aware of its internal and also external states and is able to make adjustments accordingly to create a homeostatic state. However, what is not clear in Di Scipio's description is what the criteria are for the external mapping. To elaborate, Di Scipio states that the system's interactions are the "by-product of carefully planned-out interdependencies among system components, [which] would allow in their turn to establish the overall system dynamics, upon contact with the external conditions" (Di Scipio, 2003). He also believes that this type of construction is akin to the mapping in living organisms that allows emergent behaviour to occur and we should note that these statements are all cybernetically consistent. Nonetheless, in classic cybernetic design, as employed in machines such as Ross Ashby's Homeostat, a 'criterion of stability' (Beer, 1994) is utilised to indicate a change in internal state, so that adjustments may be made to achieve homeostasis. In practical implementation this is usually some form of threshold switch, something akin to the mechanism used in a thermostat, which will, once triggered, return a certain functioning of an organism back to normal operational parameters. It would seem that this type of governor, one that is central to any cybernetic design ethos, is missing from Di Scipio's construction. There is no doubt that there must be some form of a criterion of stability otherwise the system would fail to achieve a homeostatic state. However, not recognising this as a central element in the design process could lead to extensive tuning of the input measurements (which in performance transduce into control data) in each environmental space the work is placed in, and there is much allusion to this 'tuning' process in Di Scipio's description of the set-up of the ecosystemic environment, which essentially seems to be a process of tailoring the system to that exact space to supposedly garner some desired result. All this conjecture is merely to comment that while Di Scipio's ecosystemic design is technically masterful and eminently cybernetic, there are perhaps one or two flaws in elements of its design conception that may lead to an excessive tuning process and that perhaps there are some more technically simple solutions to some of these self-reflexive design issues.

There are also some further criticisms of Di Scipio's work. The composer, Phivos-Angelos Kollias, writes, "In Di Scipio's approach the composer organises the basic organisational elements on a microtemporal level, what he calls microstructural sonic design, while any higher organizational level is left in favor of the occasional dynamics of the environment. Thus, the composer is giving away his control of the overall result. From a systemic perspective, this is a case of one directional bottom-up organization, where from the interactions in a basic organisational level emerge all higher level organizations" (Kollias, 2011). Kollias sees a flaw in this model in that it is only a bottom-up process. Whereas many cybernetic models of living organisms acknowledge the fact that organisation takes place as a balance between the different hierarchical organisational levels – top-down as well as bottom-up. As a solution to this perceived flaw, Kollias suggests "the use of the systemic principle of *equifinality*" (Kollias, 2009b). In an open system, i.e. a system in direct communication with its environment, including a self-organised system, "the same final state can be reached from different initial conditions and after disturbances of the process" (Von Bertalanffy, 2006). Kollias' hypothesis was that "if we consider the music organism as an open system, it is possible to create certain conditions in which the organism will show a tendency for 'equifinal' behavioral states" (Kollias, 2009b, chapter B). In other terms, such a conception can allow the composer to "influence the system in order to pass from a series of behavioral states, which can be similar in any constitution of the same organism under similar circumstances" (Kollias, 2009b, Chapter B)" (Kollias, 2011).

It is important to note here that epistemologically, in terms of being consistent with cybernetic theory, Kollias is correct; the human/machine/environment paradigm is the one most pertinent to cybernetics (many examples of the primacy of this paradigm are to be found in Pickering, 2011), as opposed to the machine/environment hypothesis, with the human somewhat at a removal, as modelled by Di Scipio. Furthermore, Kollias' assertion that 'proper' recursive control is 'top down' as well as 'bottom up' in cybernetic theory is also accurate (e.g. Beer, 1972) and in Di Scipio's case, this is perhaps as a consequence of his preoccupation with Xenakis' 'bottom-up' constructivist theories and his own subsequent development of a personal granular process. Nonetheless, putting these criticisms aside for a moment, what is perhaps most pertinent to consider is how Di Scipio's work undoubtedly stages cybernetic ontological theatre. In this aspect, Di Scipio's work stands as testament to what can be archived in terms of cybernetic music in a modern technological context. His work also stands as a challenge to traditional conceptions of what interactive music with computers is, and offers a rigorous and compelling alternative in both system design and compositional ethos.

The above criticisms are more of an argument as to what cybernetic composition in general should be, rather than a criticism of Di Scipio's valuable and groundbreaking musical output. This factor in itself demonstrates that cybernetic music is a self-consistent entity, with its own internal debates that differ from the standard debates that exist within contemporary electroacoustic music.

Chapter 7

The Cybernetic Compositional Framework

7. The Cybernetic Compositional Framework

Agostino Di Scipio states that the principal aim in designing a cybernetic compositional system "would be to create a *dynamical system* exhibiting an adaptive behaviour to the surrounding external conditions, and capable to interfere with the external conditions themselves" [sic] (Di Scipio, 2003). The following framework, derived from the prior research, aims to outline the conditions, precepts, and ontological position necessary for meaningful engagement in cybernetic composition.

7.1. The Cybernetic Musical Framework

This section seeks to outline the compositional practices that define cybernetic music. However, such a study highlights a fundamental paradox that lies at the heart of building a cybernetic understanding of knowledge, namely that the cybernetic worldview prioritises ontology over epistemology. The cybernetician Ernst von Glasersfeld defines this epistemological issue thus:

> "The epistemological implications of self-reference have an even wider range of influence in the cybernetical approach to the philosophy of science. Here there is a direct conflict with a tenet of the traditional scientific dogma, namely the belief that scientific descriptions and explanations should, and indeed can, approximate the structure of an objective reality, a reality supposed to exist as such, irrespective of any observer. Cybernetics, given its fundamental notions of self-regulation, autonomy, and the informationally closed character of cognitive organisms, encourages an alternative view. According to this view, reality is an interactive conception because observer and observed are a mutually dependent couple. Objectivity in the traditional sense, as Heinz von Foerster has remarked, is the cognitive version of the physiological blind spot: we do not see what we do not see. Objectivity is a subject's delusion that observing can be done without him. Invoking objectivity is abrogating responsibility, hence its popularity" (Von Glasersfeld, 1992).

Attempting to build a framework that justifies a set of cybernetic compositional practices and objectifies them as an operational 'truth' is therefore not valid in cybernetic terms. Instead the reader is asked to take this framework as a set of practices that arise from a particular worldview, a way of being, which exemplifies a mode of practice that priorities ontology and denies ultimate justifications of 'truth'. In other words this framework is not a list of rules but a set of themes that can be explored and understood through interacting with them in a performative context. Pertinent to this thesis, this framework outlines a set of compositional practices that are aimed at staging ontological theatre, and which point toward facets of true 'being'. This Heideggerian 'revealing' is the ultimate aim of this practice and therefore any mode of operation that achieves this goal is justified, not only the ones outlined here. However, examination of the work of the composers in this study points toward a common ontology that yields a certain set of practices that may be emulated in order to inhabit an ontological position that may facilitate the production of works of cybernetic music.

We may also consider this framework in terms of Pragmatism. This thesis (like cybernetics more generally) utilises metaphor in its design ethos, most pertinently for this thesis in the idea that living organisms are like machines, that cybernetic systems (such as Di Scipio's AESI, examined in chapter 6.3 and Beer's VSM[25], examined in chapter 8.2) may be applied to musical composition, and that cybernetic machines stage ontological theatre for us; that they are in some senses a metaphor for the way we might understand the workings of the world. In identifying metaphor as part of a pragmatic design ethos (as opposed to a conservative design stance), Richard Coyne states:

> "By recognising the role of metaphor it is possible to abandon the idea that there must be underlying principles governing practices. Where there are principles, they themselves are artefacts, tools of practice. [...] Pragmatism in its many guises affirms the priority of engagement in the world over theoretical constructs" (Coyne, 1995).

Here again we see echoes of the cybernetic approach to epistemology. Furthermore, in consideration of pragmatism in relation to cybernetic research, Andrew Pickering asserts that it is "an inquiry into practice *in its own right*, without a pregiven presumption that the end of enquiry has to be an argument about knowledge" (Pickering, 2011). Therefore, it is only proper to consider this framework as part of a performative idiom, not as a set of rigid edicts, but rather as a matrix of interlinking signifiers of possibility in the creation of cybernetic music in which the use of analogies and metaphors in the design process breaks down barriers and allows for the mapping of viable systems onto nascent ones, thus enabling more effective and viable practice.

7.1.1. Ephemeral Performance Works

Cybernetic music is ephemeral and different in each iteration. This is true of the works of all the composers examined in this thesis. However, a distinction must be made between ephemeral work that is constructed to be staged in an environmental space and which uses environmental sound as a key contributing factor to the resultant music (for which Agostino Di Scipio's ecosystemic music project (Di Scipio, 2003) is the principal exemplar), and other processes involving systems that create ephemeral, emergent sonorities that are recorded and subsequently manipulated (via editing and the addition of effects) to create musical works. Work of the latter type exists in a spectrum of ephemerality, from the highly ephemeral (simply a recording of one iteration of a self-sustaining musical system, of which almost infinite iterations are possible) to compositions that require a great deal of editing and manipulation, subsequent to the initial cybernetic compositional process. The works of Roland Kayn (*Cybernetics 1*, 1968), Alvin Lucier (*I am Sitting In a Room*, 1969), and Brian Eno ("2.1", from *Music for Airports*, 1978) exemplify the approach of directly recording the performance of a cybernetic music system with little or no subsequent editing or manipulation, while the works of Louis and Bebe Barron (*Forbidden Planet*, 1956) and Herbert Brün (*Futility*, 1964) represent the creation of sound elements via cybernetic processes that are recorded and later edited into a final composition. So

[25] Viable Systems Model (Beer, 1972)

we may envisage a 'sliding scale' of ephemerality, which at one extreme sees only the creation of individual sounds via cybernetic processes, and whose compositional organisation is achieved through traditional electroacoustic compositional methods and holds the final recorded work as the definitive compositional artefact, and at the other end of the scale, entirely ephemeral works that only exist at a particular time in a particular environment. Here the definitive compositional artefact is the system itself, the networks of interactions that produce the work.

In some respects the degree of possibility of truly *live* cybernetic performance is limited by the technology available in the era of its creation. For example, the sounds Louis Barron produced with his cybernetic circuits in one of the very first electronic studios were truly ephemeral and non-reproducible. However, the sound production was short-lived and could not be sustained for long periods as the analogue circuit had to be destroyed to produce the desired resultant sounds. The laborious process by which Bebe Barron edited and added audio effects to these sounds was what turned them into masterful compositions. However, as analogue synthesis and DSP became ever more available and ubiquitous in subsequent eras, self-sustainability in compositional systems became more feasible. Musical compositions produced by Kayn, Eno, and Di Scipio could theoretically last indefinitely (until the technological system failed or the electricity was turned off), with the recorded performance of these compositions being only a short excerpt from an extended musical continuum.

It is also worth considering the form that this ephemerality takes: specifically, that it is not completely indeterminate or aleatoric but that, compositionally and aesthetically, each iteration falls within a 'class of goals'. As Brian Eno would have it, the development of each iteration may be metaphorically compared to the growing of a tree; each tree is intrinsically different in its construction but at a very basic level it can be classified as belonging to the genus of trees (Eno, 1996). In cybernetic composition, the mechanism that allows for this type of structure is an heuristic (as opposed to a deterministic algorithm), which allows for general instructions that can provide indeterminate outcomes, but which still conform to a general class of outcomes.

7.1.2. The Non-necessity of Notation in the Post-literate Society

While it can be said that traditional musical structures (chords, melody, harmony, etc.) are utilised by a number of composers examined in this thesis (Brian Eno is an apposite example in this regard), traditional musical notation is definitely not present in the overwhelming majority of the cybernetic works examined in this thesis. In a number of instances, graphical scores (as is the case in Kayn's early work and Xenakis' compositions) and written instructions (as is the case with Alvin Lucier's compositions) are utilised as structural guides and in such cases we may view these strategies as a usurping of the technology of notation (Cee, 2010). However, in the vast majority of cases, notation in cybernetic composition is not necessary. This non-necessity of notation can be seen as part of a paradigm in which musical works are ephemeral and thus not designed to be identically repeated in each performance. One might think of the work of the Barrons, Kayn, or Eno, where the composer might describe the technological process of the composition for the benefit of understanding this aspect, but in performance, there is no exactly repeatable sonic result. A recording of such a work is simply the artefact of just one possible iteration that the musical system is capable of producing. Perhaps, then, the compositional act is not only in designing the musical system, but also in the choice of a particular recording that a composer may select as the iteration he wishes to stand as a testament and public record of the musical output that such a system may create.

The theme of the non-necessity of notation conforms to a Pragmatic philosophical worldview in which, in the post-literate society, text is no longer the dominant form in relation to meaning-making. The process of meaning-making is more akin to the pre-literate society, often taking the form of rite or ritual (these themes are explored many times in this thesis). In the post-literate society the auditory sense (as opposed to the visual sense, which is prevalent in the previous text-based technological age) is once again dominant and our ubiquitous electronic audio communication makes us part of a global village. This idea also relates to our use of tools in these different technological ages. To reiterate, in the technological age, tools are merely a means to an end, the end being a fixed and known goal. However, in the post-literate society, we see the incorporation of means into ends, allowing the technology to drive process and point to new discoveries. In this post-literate conception, means can mitigate ends to such an extent that the "medium becomes the message" (McLuhan, 1964). We can see this conception at work in cybernetic music in many overt ways and this is not to be unexpected in a musical form that encompasses a symbiotic link between human, machine, and environment, where technologies are used to drive process and with outcomes that are not fixed, but are instead determined through 'playing out' the interaction of these elements.

It is also pertinent to point out that representational models of reality (those that utilise symbols such as text) have proved difficult in achieving artificial intelligence (Coyne, 1995; and Hofstadter, 2007). Platonic ideas of perfect forms, and Cartesian mind/body splits, which are also synonymous with classic A.I. research, have also proved problematic in cognitive modelling. It is no surprise then that artificial intelligence has moved in recent years to a more constructivist and performative view of cognition as an aid in understanding the problems of "hard A.I." (Thorisson, 2009). This fact has ramifications in the design of self-referential and reflexive machines. It follows, that in thinking about 'intelligent' music-making machines or real-time interactive compositional systems that incorporate machines as autonomous entities, ruling out a cybernetic paradigm would be to close off many possibly fruitful lines of inquiry.

7.1.3. The Decentring of the Composer

We see the trait of the de-emphasis of the composer's role in the compositional process in the work of all of the composers selected for evaluation in this thesis and perhaps this is not surprising in a musical form that embraces probabilistic process and non-hierarchical control structures. Examples of this conception can be found in the fact that the Barrons did not initially consider their work as musical composition, in Lucier's assertion that Edmond Dewan was the true composer of *Music For Solo Performer*, in Brün's theory of 'anticommunication', which aims to usurp the role of the traditional composer's ability to imbue meaning in his compositions, in Kayn's rejection of notation and traditional methods in favour of a human/machine/environment paradigm, in Eno's conception of "being an audience" to the results of his compositional systems and in "riding the dynamics" of a system, rather than "specifying everything in detail", and finally, in Di Scipio's assertion that the role of the composer in interactive composition should be to compose the interactions and thus relinquish traditional ideas of compositional control in performance.

We may see these compositional practices as being precisely aligned with a more general decentring of the self that lies at the heart of cybernetic ontology. Andrew Pickering attests: "Cybernetic models of the brain, and understandings of the self, point immediately to a decentring of the mind and the self […] the cybernetic preoccupation with adaptation has continuously eroded the modern understanding of the bounded, self-contained, and self-moving individual. Instead, one has the image of the brain and the self as continuously bound up with the world and engaged in the process of coupled becomings. […] [This conception places the] emphasis on undoing the modern self for the sake of an awareness of being, instead, part of a larger whole" (Pickering, 2011). Furthermore, the assistive technology paradigm associated with cybernetic machines sees the machine as a partner in endeavours, rather than merely a tool. Thus, if machines are viewed as partners in creative projects, it is possible to see a clear decentring. In the human/machine/environment paradigm of cybernetics, no one entity can claim entire authorship.

One further comment on this element of cybernetic composition should be noted, namely that there is reluctance on the part of some composers to relinquish the dominant agency of the composer in the creation of their musical works. This may be seen in Eno's insistence on embellishment, once the systemic process is completed, in order that the work is moulded to live up to his desired aesthetic standard, or in Lucier's insistence that the technological process had little to do with the outcome of his compositions. Two observations can be made here: firstly, those who have made composition their lifework may not want to relinquish some of their authorship for reasons of legacy, and perhaps in some cases, for copyright issues. Secondly, the role of the composer's aesthetic is something that should not be ignored in cybernetic composition; it is just as valid as machine idiosyncrasies or environmental probabilistic elements. The cybernetic system is one that gives equal relevance to all parts of the system, as long as no one element is dominant it will conform to cybernetic principles. On this point it is worth reiterating that cybernetic composers do not intentionally imbue their work with meaning. Cybernetic music does not take the audience through a constructed, narrative, emotional journey, as is the intention of much composition in the Western art tradition. Instead, meaning is an emergent property of the music, which may be freely interpreted by an audience. Here again, in this recognition of how meaning is made in cybernetic composition, we can see a decentring of the composer.

7.1.4. The Inclusion of the Environment in Composition

The recognition of the role of the environment in cybernetic music is central to the compositional ethos. This aspect may be seen in the Barrons' analogue circuits, which were operationally sensitive to environmental conditions. It is also apparent in Lucier's compositional systems, which transmute information from the human, through technology, into the environment and back again, and again in Eno's ambient music, which mingles with environmental sound to create the finished work. In cybernetic terms, all entities are situated in environments; they evolve from these environments and are inseparable from their contexts. It is through interactions with an environment that entities come to *be* and all learning and cognition are formed as a symbiotic coupling with an environment.

In terms of cybernetic music, this fundamental relationship with the environment may be considered in a number of different ways. Firstly, it is important to remember that cybernetic conceptions of the environment stem from Norbert Wiener's original inspiration for cybernetics, in particular the fundamental probabilistic properties of the universe and the ontology of unknowability that this precipitates (Wiener, 1948). This worldview lies at the root of much of the subsequent cybernetic enquiry leading to the 'order from noise' principle (Ashby, 1947; and Von Foerster, 1960), autopoiesis (Maturana and Varela, 1980), and a performative model of cognition (Von Glasersfeld, 1999).

To embrace these concepts in composition means to recognise that probabilistic processes are at play in the compositional act. If applied to traditional conceptions of composition this would mean that a composer would recognise that all the factors in the compositional process, from the placing of notes on paper to the work's realisation by an orchestra, are subject to probabilistic processes, and acknowledgement of this fact would be made apparent throughout the compositional process and also in the playing of the work. As we may discern from the orchestral example above, almost all of the probabilistic processes active within this conception stem from interaction with an environment, from what a composer might have listened to before writing the composition, to the temperature in the concert hall microtonally affecting the instrument tuning (or for that matter whether a butterfly flapped its wings in Brazil!) – and thus an inexorable link between interacting with environmental conditions and probabilistic processes may be seen. Of course, in practice, all traces of probabilistic processes are conceptually expunged from all stages of this type of compositional process, despite their inevitable existence. However, recognition of probabilistic processes is the purview of much experimental music (and, for that matter, the music of pre-literate societies and many types of folk music (Cee, 2010)).

In his paper "Generating and Organizing Variety in the Arts" (Eno, 1976), Brian Eno draws distinctions between types of music that mirror biological systems, which he distinguishes as being cybernetic, and those that do not, in other words, those that recognise environmental and probabilistic processes, and those that deny their existence. This definition links the modelling of biological processes in composition with the consideration of environmental conditions and thus we may view this facet as being an important conceptual standpoint in cybernetic composition. The conceptual linking of biological modelling with environmental processes is important, as not all cybernetic music systems appear to have a direct physical coupling with the environment (as might be exemplified by a microphone providing the sound source for a real-time composition). However, all these conceptions conform to a biological modelling paradigm that recognises probabilistic processes and therefore an environmental paradigm has been evoked. The Barrons' conception of biological modelling in their circuit design is an apposite example of the evoking of an environmental paradigm.

Furthermore, one may consider that where a direct coupling with a real environmental space is not utilised, the composer will often attach additional conceptual environmental concerns to the piece. Examples here would be Eno's requirement that his music should be low in volume and mingle with the environment, Brün's desire for a usurping of the expectation of his audience so that meaning may be interpreted more freely (a contextual environment), and the Barrons' music being considered as both sound-effects and music, thus mingling non-diegetic music with the diegetic sounds of the film's environment.

Secondly, in terms of traditional composition, probabilistic processes and environmental conditions are conceptually viewed as *errors* that must be erased to conform to a platonic idea of a perfect form. Conversely, from a cybernetic viewpoint, error is the process by which living organisms learn. Adapting to error makes organisms flexible and reflexive (Beer, 1972). Thus, conceptually, in designing cybernetic music systems, we must consider the incorporation of error. In cybernetic terms, we must consider this concept in relation to variety and noise. According to Ashby's law of requisite variety (Ashby, 1956), in order to be self-reflexive, any machine or organism must be able to adequately encapsulate all the information it receives from an environment in order to process, adapt, and react to it: an organism's internal variety must be equal to the external variety it is presented with (Ashby, 1956). Variety in any given environment may be very high and contain a lot of informational noise, thus an organism's receptors must be able to adequately capture a full range of environmental signals and must at the same time be able to filter out unwanted noise. It is also required to amplify quiet signals when necessary (Beer, 1972).

In order to understand how the cybernetic concept of variety might manifest itself practically in electronic music terms, it is useful to consider an audio processing device known as a *compressor*. A compressor is a non-linear amplifier that attenuates loud signals and amplifies quiet signals. It utilises a transfer function to determine the threshold volume of sounds that need to be attenuated or amplified and it performs this task automatically, as the audio signal is passed through it, to maintain an even volume. Compression is used ubiquitously in popular music production to produce a consistent volume level, despite the possibly large variation in the dynamics that may exist in an original recording. However, the use of compression on quiet signals can often contain a large amount of ambient noise as this sonic element is also amplified, along with the pertinent, quiet sounds in the environment. In practice, in order to reduce the noise that may be enhanced by the use of compression, the threshold of the transfer function has to be set in such a way as to produce the maximum level of the pertinent signal with the least noise. Therefore a degree of tuning is essential in attaining the desired result. Thus we may see the concept of variety in action in audio technology, where signals can be amplified or suppressed, and with the correct threshold setting, with the minimum amount of noise. It is also interesting to consider that signals that contain a lot of noise are much more prevalent in popular music recordings than in recordings of say classical music; this element of noise or 'error' is accepted as the norm in popular music recordings.

In a cybernetic music system 'error' or noise can be utilised in a number of ways: In the Barrons' case, the instability of the operation of their circuits would produce unintended sonorities. In Eno's case the unpredictability of the Koan software would produce compositional structures that could not be pre-imagined by the composer, and in Di Scipio's case the ambient 'noise' of the environment produced probabilistic compositional determinants. In Di Scipio's case, the environmental coupling of the composition is perhaps the most organic conception of the use of error or noise in the compositional process. Here the noise of the sound itself provides the data for the recursive control mechanism operating internally in the computer.

In terms of cybernetic composition, it is worth considering how such a recursively coupled system might operate autonomously and also allow a composer to interact with it in real time. In this conception a composer would manipulate incoming signals using DSP and then react to the resultant audio in order to adapt the overall sonic output to produce a desirable outcome. In the cybernetic conception of such a design the computer would also be required to operate autonomously if required. To facilitate this autonomous functionality, criterions of stability (C of S) (Ashby, 1952; and Beer, 1972) would need to be set in the DSP in order that these audio processors may react to external conditions in the desired way. In implementation, these C of S would be threshold switches (just like the transfer function in the compressor), which would be set, usually through tuning when embedded in an environmental setting, to a threshold of 'too much' or 'too little' of any given element, in order that a set of operational parameters may be defined for DSP functions that control or modulate elements of a composition (for example, changes in amplitude, frequency content, note density, etc.). So, in this model of a cybernetic compositional system, error (and the testing of it in a tuning process) performs a function in how a system learns to adapt to its environment to produce a musical piece that falls within a class of goals, rather than a fixed result. Error can never be expunged from such a system and often errors can be a useful source of unpredictability and innovation in the resultant soundscape.

One final point must be made in relation to the role of the environment in cybernetic composition: in the design described above, sound is captured from the environment and manipulated via DSP processes and subsequently fed back directly into the environment in an on-going feedback process. This recursive coupling is perhaps the most vital form of cybernetic composition as it most accurately models how living organisms achieve autopoiesis. In this conception of cybernetic composition, the environment is not a theoretical construct or modelled representation, but a real environment reacting to sound in real time. As Di Scipio notes, in his ecosystemic model, "sound is the interface" (Di Scipio, 2003). However, it must be noted that in Di Scipio's system, the human is somewhat removed from the human/machine/environment paradigm, as the system is fully automated during performance. Thus a spectrum of environmental coupling within cybernetic composition may be considered, with Brün's closed-system computer compositions at one extreme, and Di Scipio's ecosystemic model at the other.

7.1.5. A Systemic Human/Machine/Environment Design Ethos, which Necessitates the Composing of Interactions rather than Interactive Composing

The use of systemic processes in modern composition, particularly those that utilise technology, is pervasive. However, what must be considered here is the specific type of system utilised in cybernetic composition and how it differs from traditional approaches to composing music with technology. In examining such a system it is perhaps pertinent to consider what is meant by 'music' in this context. In terms of cybernetic composition, music is an emergent property of the interaction of structural elements at play within the composition. This musical result is not preordained (particularly not by notation), but instead falls within 'a class of goals', the scope of which is determined by an heuristic conception (think of Pask's Musicolour machine getting 'bored' and adapting its behaviour accordingly). In practical terms, an heuristic can be modelled via a matrix of interactions and criterions of stability that can determine the internal state of a system in relation to external conditions. For example, a change in state *a* in the environment alters the condition of modulator *b* in the computer, which, via the matrix, in turn alters the state of modulators *c* & *d*, the resultant sound of which is fed back into the environment and thus changes state *e* here, which in turn changes the state of modulator *c*, which then alters the state of modulators *a* & *d*, and so on. This matrix design of interactions is not arbitrary, but the result of carefully worked-out composition, the purpose of which is the production of emergent properties that may be considered as music. The compositional emphasis in cybernetic music is on the design of these interactions and how they might respond to environmental factors and manipulation by a composer in real-time performance.

This emphasis on 'process over product' and music as an emergent property of a system can be seen in the work of all the composers considered in this thesis, ranging from Brün's modular 'sawdust' process[26] producing emergent sonorities in his computer compositions, through Kayn's intricate modular patching matrices producing homeostatic soundscapes, to Di Scipio's emphasis on composing interactions as opposed to interactive composing.

In his 2003 journal article "Sound is the interface: from interactive to ecosystemic signal processing" (Di Scipio, 2003), Di Scipio makes some useful distinctions between traditional interactive, real-time compositional models and the cybernetic model. He states that in the traditional real-time compositional model the human performer is the only agent capable of altering the internal state of the computer device, and is thus the only element in the system that closes the feedback loop from environment to the machine. The problem in this model for Di Scipio is that the recursive coupling is only made possible by the agent performer. If he/she is removed from the system, it leaves only a linear information flow, from the machine to the environment. Furthermore, he expresses his frustration that this linear design ontology is "the only way we may think of when speaking of such things as 'live electronics' and 'interactive music'" (Di Scipio, 2003). Di Scipio therefore postulates a

[26] A description of which can be found in Di Scipio, 2002.

new compositional model, one in which the computer is able to register its own internal state and affect the sound world in the environment in real time, with no interaction from a human agent necessary in performance. In this model, the composition occurs prior to the performance, but instead of this being a matter of notes on paper, it takes the form of the technological design of interactions that determine the emergent properties in the performance.

One criticism of Di Scipio's ecosystemic approach in relation to this thesis and cybernetic music more generally is that it makes the composer somewhat redundant in performance and thus the cybernetic/assistive symmetry of human/machine/environment is broken and consequently the role of agent-performer is significantly diminished. In criticising standard interactive composition, Di Scipio states:

> "On a closer look, the role of the agent-performer appears itself ambivalent (no criticism implied), in that it is the only signifier of the system's external conditions and, at the same time, it represents an internal component of the overall meta-system including man, machine and environment. Indeed, in this common notion of interaction, the agent is indeed the interface between the computer and the environment, and, at the same time, it is the only source of energy and change" (Di Scipio, 2003).

This critique of a linear design ontology is valid from a cybernetic standpoint, in that the machine has very little agency in the systemic design. Furthermore, Di Scipio implies that in this conception, there is a systemic imbalance in the role of the human agent; she/he is at once the only source of energy and change, but is also an integral, internal component of the system. There are some instances in which this linear design ontology can yield more equilibrium in the human/machine/environment symmetry. Firstly, where sound flows through the environment and back into the system in a recursive coupling (via an audio feedback loop), the environment has much more agency in the performance. Secondly, where the computer interface is designed with inbuilt complexity (for example, a myriad of choices of elements of change, engendering more variety or noise, in Ashby's terms), the human performer gains less agency in the shape of the musical output, and thirdly, where the performer's conscious agency is somehow diminished via the interface with the electronic system (in the use of brainwaves to drive a performance, for example). In each of these conceptions of Di Scipio's linear design ontology, the human/machine/environment symmetry is rebalanced so that the system becomes less of a subservient tool for producing fixed results and more of a systemic process for driving process and pointing toward new discoveries.

It should also be noted that in Di Scipio's ecosystemic design, the human interaction with the system takes place before the performance and is thus similar to traditional composition; in the ecosystemic conception, notes on paper have been replaced by the design of interactions. However, Di Scipio does leave open the possibility of human interaction by an agent-performer in the ecosystemic model, in his triangular recursive connection model (Fig. 23, on page 123 of this thesis; Di Scipio, 2003), and it is the contention of this thesis that this open model, one that includes an agent-performer in the ecosystemic model, is a more cybernetic conception of musical composition – one in which the machine is an equal partner to the human agent in the compositional process.

7.1.6. Compositional Design based on Feedback or Recursive Coupling

Feedback is a central cybernetic mechanism. Without acknowledgement of this phenomenon, or its actual use as a central element, a compositional system cannot be considered cybernetic. A cybernetic system must form a feedback loop between human, machine and environment and in its ultimate conception these elements must be reclusively coupled in such a way that change in one component affects all the others. Embracing feedback in this way is also recognition of the phenomenon of circular causality, as opposed to traditional cause-and-effect paradigms. This has implications in composition in terms of the human/machine/environment design ethos, the necessity of the inclusion of the environment in composition, and (in the recognition of circular causality) the decentring of the composer. We may see examples of feedback processes in all the composers examined in this thesis: in Louis Barron's feedback circuits; in the 'slow-motion' feedback process of Alvin Lucier's *I am sitting in a room*, not to mention the circular causality implicit in *Music for Solo Performer*; in Brün's theory of anticommunication, which emphasises a feedback loop between audience and music in performance; in Roland Kayn's recursive coupling between sound creation and sound control; in Gordon Pask's adaptive learning machines; in Brian Eno's network of interactions in his use of the Koan software; and finally, in Agostino Di Scipio's ecosystemic design, in which recursively coupled sound becomes the interface.

Design and manipulation of feedback processes is probably the most potent device in cybernetic composition. Recognising and controlling the feedback loops in a compositional system has the greatest potential for creating self-sustaining and reflexive musical systems, ones that are 'aware' of their own internal states and recognise and respond to changes in the environment to organise sound elements in real time in order to create music.

As has been noted previously in this thesis, both positive and negative feedback can be used in the design of cybernetic systems; one creates exponential possibilities, the other controls them, and thus a state of equilibrium with an environment can be achieved. In cybernetic compositional terms, positive and negative feedback is utilised via DSP processes in the computer that react to sound in the environment and shape the overall parameters of a composition. Again, Di Scipio makes some useful distinctions as to how DSP process may be utilised, via feedback mechanisms, in shaping the sound of a cybernetic composition. These include functions that 1) compensate (reduce the amplitude of audio inputs); 2) follow (copy the value of a given value, sometimes with a time delay); 3) control redundancy (to increase the number of grains output, thereby increasing the intensity of the overall sound); and 4) control concurrency (support a contrasting sonic feature, e.g. boost low frequencies when high frequencies are prominent) (Di Scipio, 2003). Di Scipio utilises bespoke granular processing in order to achieve these control mechanisms. However if we apply cybernetic principles, this shaping of the soundscape via feedback mechanisms is a question of variety management – as employed in Beer's VSM (Beer, 1972) – and in terms of cybernetic composition, may be achieved with any number of DSP processors, including 'off-the-shelf' audio 'plug-ins' that are to be found in the majority of sequencing software packages, such as filters, compressors, envelope followers, distortion, delay, etc. However, most musical sequencing packages are strictly linear (in playback terms) and therefore recursive coupling is not possible in such a system. Thus software systems that allow for recursive coupling in real-time performance must be sought (the author's solution in most instances is either Ableton Live or Max/MSP, but many more 'open-ended' sound-design and organisation software packages are available on the market). In order to allow for recursive coupling to take place, the ability for audio to be recorded and played back in real time must be available. Furthermore, the capacity to measure particular aspects of the incoming audio data must also be available (e.g. amplitude, frequency, spatial characteristics, etc.), and the ability to link this data to DSP control parameters must also be possible, so that internal automatic manipulations based on external conditions can take place. The ability for a composer to interface with the computer (usually via a control surface) is also preferable in order that the dynamics of the system may be altered in real time, and 'pushed' in desirable directions.

In this conception of a cybernetic music system, feedback is the driver of the design ethos and careful consideration of this precept is essential to successful design.

7.1.7. Ontological Theatre – Heideggerian Revealing

Finally, we arrive at the underlying purpose of undertaking composition in the cybernetic mode, namely that it might reveal facets of true 'being', in the Heideggerian sense. This could easily be viewed as a hyperbolic enterprise – why should it be the purview of composition to achieve such a lofty aim? Nonetheless, when we consider that all the composers in this study have a quiet preoccupation with 'being', this proposition begins to take on a different inflection. Much of this pensiveness stems from the ontological questions posed by enquiry into the modelling of biological systems and the themes of emergence and becoming that surround this enquiry. In Brian Eno's case, this preoccupation centres around how "things come into being" (Whittaker, 2003) in the emergent forms his generative music systems precipitate. In Alvin Lucier's case it is manifest in his expounding of W.C. Williams quotation, "no ideas, but in things" (Harder and Rusche, 2013). In Roland Kayn's case, this aspect manifests itself in the mode of listening that cybernetic music engenders, where "existential being, as it were, takes the place of a logically functioning consciousness" (Kayn, 1977), and even in the Barrons' very grounded approach, the preoccupation with creating synthetic life demonstrates a concern with ontological questions.

It is not unsurprising that composers who are influenced by cybernetics demonstrate a concern with ontology, as cybernetics itself demonstrates this preoccupation at a fundamental level. However, the specific 'black box' ontology of unknowability that is synonymous with cybernetics leads to a performative worldview, one in which we may only know the world through interaction with it. Consequently, all designers of cybernetic artefacts (we might think of Norbert Wiener's Hearing Glove, Ross Ashby's Homeostat, or Gordon Pask's Musicolour Machine) are directly engaged in demonstrating some facet of how the world might work. Thus, as Andrew Pickering points out, cybernetic projects stage ontological theatre for us. It therefore follows that we should consider cybernetic composers in the same light as cybernetic machine builders, with their compositions being stagings of ontological theatre that demonstrate some facet of how the world might work in practice. Here, we also see the employment of metaphor as design ethos, the idea that these works are metaphors for facets of the way the world might work if we adopt a cybernetic ontology.

As has been demonstrated many times in this thesis, this innate capacity to stage ontological theatre chimes strongly with Heidegger's conception of technology's capacity to reveal 'true being'. Heidegger asserts that technology is intertwined with our being; it comes from us and is inexorably tied to our existence. Nonetheless, it is a destructive force that conceals true being. However, if we are able to participate in technology in a more radical way and thus usurp its intentionality in some respect, then we may combat its enframing power and thus reveal facets of true being. So, whether intentional or not, all cybernetic composers are engaged in Heideggerian revealings as they practically create cybernetic artefacts (musical works realised via technological means) that stage ontological theatre for us. We can recognise this facet in all of the cybernetic composers examined in this thesis, from Louis Barron's biologically derived circuits, through Eno's generative systems, to Di Scipio's ecosystemic compositions.

Chapter 8

Original Cybernetic Compositions

8.1 *Oscilloscope* – Cybernetic Principles and Sonic Ecosystems

Please note: An example recording of Oscilloscope, the computer animation and software files can be found on the materials accompanying this thesis.

Oscilloscope is an ecosystemic installation piece incorporating sound and computer graphics that was realised in collaboration with Adam Collis who programmed the computer animation. The piece was originally designed for the launch night of Coventry's UK City of Culture Bid for 2021 and was first presented at Warwick Business School at the Shard in London in June 2015. It was also presented at the International Computer Music Conference in Utrecht in September 2016.

The practical design was inspired by the work of two composers examined previously in this thesis – namely Brian Eno and Agostino Di Scipio. The generative music system was inspired by Brian Eno's non-contiguous loops, which he utilised in tape-based compositions such as "2.1" from *Music For Airports* (1978).[27] The interactive elements of the composition took inspiration from Di Scipio's ecosystemic design ethos, which is exemplified by his AESI project.[28] Despite the different idioms that these practitioners work in, there are conceptual commonalities in the generative music of Brian Eno and the musical ecosystems of Agostino Di Scipio. The work of both these artists is influenced by principles of cybernetics, in particular the notion of 'emergence', where the composer's role is not in designing outcomes but in designing systems, whose component interactions produce desirable outcomes. A synthesis of these ideas is applied in the design of *Oscilloscope*. This design ethos demonstrates how a system that is relatively simple technologically and has fairly trivial initial sonic and visual material can be tuned to produce interactions that generate complex results and provide a rich, engaging experience for the audience.

In *Oscilloscope*, measurements of light from the environment (as opposed to measurements of environmental sound in the AESI) feed information to the computer about changes in light intensity in the external environment. This transduction of light information from the environment is cybernetic in its use of metaphor to be found in the mapping of one system onto another; in this case, changes in light map to the movement in computer graphics and sequential and tonal changes in the soundscape. However, it is important to state that this mapping is not of the linear cause-and-effect variety, but is instead achieved through a matrix of interactions that also link elements of the animation and music software, thus mirroring the mapping in the AEIS, which pertains to a cybernetic modelling of biological systems.

[27] See chapter 6.2 for a full description of this piece.

[28] See chapter 6.3 for a description of the AIES.

8.1.1 The Cybernetic Influence of Eno, Di Scipio and Xenakis on the Composition of *Oscilloscope*.

While both Eno and Di Scipio have explicitly cited cybernetics as an influence on their work (Eno in Whittaker, 2003; Di Scipio, 2003), they have also made overt reference to other composers who have utilised cybernetic techniques that have influenced their compositional process. Of particular interest to the development of *Oscilloscope* is the fact that both composers build on compositional ideas espoused by Xenakis (Eno in Whittaker, 2003; Di Scipio, 1997 and 2003).

As examined in chapter 6.3 Xenakis endeavored to "generalize the study of musical composition with the aid of stochastics" (Xenakis, 1963). To this end he utilised the methodology found in W. Ross Ashby's 1956 book, *An Introduction to Cybernetics* (Kollias, 2008). From his reading of Ashby's work, Xenakis proposed that "second order sonorities" could emerge from the interactions of sonic grains: that interactions of grains over time in the compositional process, at a "micro level", would form emergent timbres and compositional gestures at the "macro level". Although both Eno and Di Scipio have criticised Xenakis' approach (Eno in Whittaker, 2003; Di Scipio, 1997), the idea that emergent (musical) behaviour at a macro level can arise from composed interactions at a micro level underpins both composers' working methods and the design ethos of the music and computer graphics in *Oscilloscope*.

At root, both Eno and Di Scipio share the desire to create autonomous musical systems that are modelled on the way in which living systems generate complexity, which can also manifest as emergent behaviours. Both composers reject the linear design ontology of the majority of interactive computer music systems in favour of ecosystemic systems design[29] – a constructivist ethos in which the design of interactions of a system's components, prior to performance, takes precedence over a macro musical design, shaped by a composer during a performance in real time. Di Scipio notes that, "this is a substantial move from interactive music composing to composing musical interactions" (Di Scipio, 2003).

As highlighted in chapter 6.2, Eno first encountered cybernetics as an art student in Ipswich in the early 1960s under the tutelage of Roy Ascott. He later read Stafford Beer's book *Brain of the Firm* (1972), from which he has quoted extensively and which he has used as a justification for his compositional approach (Pickering, 2011). Thus we may see a preoccupation with systemic design, one based on cybernetic theory, in Eno's compositional process. Andrew Pickering believes that the cybernetic systems that Eno utilises in this compositions "can thematise for us and stage an ontology of becoming, which is what Eno's notion of riding the systems dynamics implies" (Pickering, 2011). In addition, Eno observes that this type of compositional system generates "a huge amount of material and experience from a very simple starting point" (Eno, 1997), further emphasising the cybernetic tropes of becoming and emergence in his work.

[29] see chapter 6.3 for elaboration of Di Scipio's ecosystemic composition and 6.2 for the influence of biological systems on Eno's compositional methodology.

Eno's generative music systems have been realised by a number of different technological means, including the VCS3 synthesiser, analogue tape manipulation, and the Koan generative music software. The method emulated in this composition takes inspiration from Eno's tape-based composition "1/2", from the album *Music for Airports* (1978). As examined in chapter 6.2, the design of "1/2" consists of individual vocal sounds (wordless 'aaahh-sounds' in the key of F Minor), recorded onto separate lengths of tape between fifty and seventy feet long (Sheppard, 2008). These tape loops were then played back simultaneously, but not synchronously, and the results were recorded to multi-track tape. The timing of the piece, of when each vocal sound would play, was determined by the length of each tape loop, meaning that notes would at times coalesce to form chords and shifting melodies and at other times there would only be individual notes or silence. In Oscilloscope, an analogue of Eno's tape based has been designed in the Ableton Live software. This construction will be examined in section 8.1.3. of this chapter.

Di Scipio's design ethos is one that encompasses the environment in the human/machine interaction, and thus embraces a tenet that is central to the cybernetic ontology. In Di Scipio's conception of ecosystemic design, which he implements in the AESI, the structure should be capable of being a 'self-observing system' (independent from an agent/performer), one that is capable of tracking what happens both externally and internally and making adjustments accordingly. The system is an environmentally coupled feedback loop, meaning that when changes occur in the state of the environment, they are registered by the computer, which then alters its own internal state in response to external environmental conditions. These internal changes are then played out into the environment and thus an on-going feedback process is established. In the AEIS, interaction is no longer in the form of "agent acts, computer reacts", as is the case in the traditional linear model of electronic music performance (Di Scipio, 2003). The flow of energy in the system is no longer one-way (i.e. from the composer, via the computer, in real time); energy may be derived from the environment and a composition may be self-sustaining, with little real-time input from a composer/performer.

The influence of Di Scipio's AESI is reflected in this composition in the design of the environmental interactions, which drive the tempo and the structure of the musical composition and the accompanying computer graphics. The influence of the AESI design is examined in section 8.1.4, later in this chapter.

8.1.2 System Design and Implementation

Oscilloscope is an installation featuring sound and computer animations generated in real time in response to image data from the installation's environment captured by a camera. The original animation was made in Apple's Quartz Composer software, which reads image data from an attached camera, and from which individual pixel data is used to stimulate the movement of the graphics, as well as for controlling the playback of audio loops in Ableton Live on a second computer.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Subsequently, however, the generation of the graphics has been changed so that it is now performed in Processing 3[30]. Inter-application communication is achieved using Open Sound Control. In the system design shown in Figure 25 (above), we may see that Computer 1 reads in image data from a USB webcam and reads pixel values using Apple's Quartz Composer software. Within Quartz Composer, this data increments the phase of sinusoidal functions, the outputs of which are sent via OSC to Processing 3, which generates the visuals to be projected. At the same time, when the outputs of these functions reach threshold values, trigger messages are sent via OSC to the second computer running Ableton Live in order to play or stop looped tracks (Collis and Pickles, 2016).

In the development of the piece, the generative computer animation was designed prior to the music and the interactive systems that would link the sound and music to changes in the environment. Consequently, the audio material selected for the composition reflected the emergent properties of the computer animation, which was visually akin to a jellyfish swimming through an ocean, thus the sampled sound utilised was metaphorically linked to water to reflect this aesthetic.

8.1.3 Audio Implementation

The emulation of Eno's tape-based system is achieved using the Ableton Live software. Loops of tape are substituted with non-contiguous loops of audio samples, which, when played simultaneously, never repeat the same sequence twice. Thus a complex, laminar, and ephemeral composition emerges. The sound materials that make up these loops reflect the aesthetics of the visuals.

Fig. 26 (below) shows a screen shot from the Ableton Live software running the *Oscilloscope* composition. At the top left hand side of the screen we can see the Tempo, which is linked via Open Sound Control to the speed of oscillation of the animation; as the animation speeds up, so does the tempo. In the middle of the screen we can see a matrix of audio clips, which are triggered to play or stop depending on changes of levels of light in the environment. At the bottom right of the screen we may see inside one of the clips being played. What can be observed here is a MIDI piano roll with one note, which will be triggered to play after 19 bars once the clip has been triggered to play.

[30] "Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts." https://processing.org.

Fig. 26. Screenshot of Ableton Live software running the Oscilloscope composition.

Each clip is designed to trigger a sample to play at a predesigned time between 0 and 40 bars once it has been triggered by changes in light intensity in the Environment. This process mirrors Eno's tape loop compositions as each clip is a loop and each loop is non synchronous. Therefore, just as is the case with Eno's compositional system in "2.1" (from *Music For Airports*, 1978), no two performances of a piece are the same.

Fig.27. Example of contents of an Ableton clip in the Oscilloscope composition

Many of the samples are also subject to real-time digital signal processing techniques, which are controlled by automated control envelopes. The speed at which the envelopes move through their control cycle is determined by the tempo and thus changes with alterations in overall light intensity. Thus, through these structured interactions, an autonomous autopoietic musical and visual system is achieved.

8.1.4 Design of Environmental Interactions

Further generative interactions were designed and inspired by Di Scipio's compositional method in the AEIS; Di Scipio's design ethos has been adhered to in the creation of this piece via the interactions between the environmental input of the camera source and the musical and visual software. A grid of twelve discrete point sources is derived from the incoming image produced by the camera and changes in light intensity of these sources indirectly trigger individual sample loops to play or stop.

Fig.28. The visual representation in Quartz Composer of the 12 points of light from the camera.

Intensity values increment the phase of sinusoidal functions of the visual material, which outputs 'play' or 'stop' messages to individual sequencer tracks once threshold values are crossed. In this way, the twelve light-point sources are mapped to thirty sample loops to create a matrix of non-linear triggering possibilities.

Fig.29.Mapping of camera input in Quartz composer to visual and audio data (Designed by Adam Collis, 2016). The Macro patch in the bottom right of the image maps the 12 points of light to controller information in Ableton Live.

Thus, the rate of change of individual sonic and visual components within the installation is constantly changing in response to light conditions in the surroundings as read by the camera. The speed of one loop of the visual material also determines the tempo of the sequencing software so that a higher speed will generate more triggering opportunities.

Fig.30. Depicting the internal wiring of the 'Macro patch' in which a mapping of 12 light sources from the camera to MIDI controller data in Ableton Live can be seen (designed by Adam Collis 2016).

It is important to state that the musical system in the Ableton Live software can operate in a generative way without linkage to the camera and the interactive systems. However, the interactive mapping to the camera system allows for a much more complex compositional structure and aesthetically interesting composition. Furthermore, the system does not have to be recursively coupled to function autopoietically. However, in performance, the system may be recursively coupled in some creatively interesting ways that represent a staging of ontological theatre. In its simplest arrangement, recursive coupling may be achieved by pointing the camera at the screen displaying the computer animation, with the sound being the audible traces of this interaction, or the camera may be pointed at performers (or dancers) who are moving and reacting to both the sound and the animation in a recursive way. A performance of this arrangement with the Oscilloscope system was achieved in practice with the dancer Polly Hudson at the Vivid Art Projects Space in Birmingham on 8 October 2015.

Unlike Di Scipio's AEIS, the interactive mapping utilises 'criterions of stability' (Beer, 1972) in the form of threshold triggers. In the Oscilloscope system design, threshold triggers are set so that light of a certain intensity (from a number of light-point sources) will trigger an action (for example, to play an audio loop or to begin a cycle of DSP functions), and conversely, below a certain threshold, functions in the internal mechanism will switch off or change their state. Once the operational criteria of stability have been set in an environment of average light and movement, very little additional tuning is required in different performance environments, and again we see a converse arrangement in the functionality of Di Scipio's AEIS.

8.1.5 Computer Graphics Design

The shifting geometrical shapes in the visual material are made from two "rings", each constructed out of a triangle strip, joined together end to end. Figure 2 shows how the structure of one ring is made up with the shading removed and the lines of each triangle made visible. Alternate vertices of each ring's triangle strip define a closed loop and so the whole shape can be described by three loops: two at either end and a loop common to both rings at the shape's centre where the rings join. The shape, as seen in the animation, is shown in figure 3.

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Fig. 31. One of the rings that make up the moving shapes of the image. Lines connecting the vertices have been made visible to show how a ring is made from a triangle strip joined at both ends (A. Collis in Collis and Pickles 2016).

A closed loop such as a circle or ellipse is defined by a two-dimensional sinusoidal equation. Therefore, the animation of each of the loops can be achieved through modulation of the amplitudes and frequencies of their sinusoidal components. In Figure 2 it can be seen that these equations determine the location of vertices in the y and z planes, but in addition, a third sine wave component is used to vary the x positions of the vertices and thus modulate the "width" of the ring. In this work, these amplitudes and frequencies are themselves modulated by sine waves of fixed amplitudes, but whose phase is incremented by pixel values from the image data obtained from the camera. Through this process, arbitrary motions can be created in response to the environment, but within limits set by the creators of the work.

Complex motions can therefore be achieved with fairly simple mathematical processes similar to AM and FM synthesis processes familiar to the computer sound designer. Thus, although the basic shape is very simple, the layers of modulation processes on the shape's structure create complex bio-mimetic movement, giving the visual effect of a highly abstracted sea creature. However, the point of interest here is that this bio-mimesis arose, not from a 'top-down' design that seeks to emulate the totality of complex movements, but from the set-up of multiple modulations whose unpredictable interactions generate patterns that can be seen as an emulation of the motion of a living organism. As a result of this mimesis, sound samples are used that have a direct correlation to water, and which reflect the emergent properties of the animation (A. Collis in Collis and Pickles 2016).

Fig. 32. The complete shape (with connecting lines removed and shading added) made up of two rings (A Collis in Collis and Pickles 2016).

8.1.6 Conclusion

Although it is recognised that this installation is conceived in the digital domain, the title *Oscilloscope* – which refers to a form of analogue computer display – was chosen to reflect the critique of common assumptions of digital technology that this work represents. The processing of discrete bits of information facilitates linear mapping formulae where a single input value produces a related output value. With such an approach, there is a tendency to produce complexity through accretion; either the accumulation of more inputs and outputs, or the linear chaining of mappings between a single input or output. With this work, the aim was to avoid such linearity between the visual input data and the resulting material through the designing of low-level interactions between simple materials. The sounds and visuals of the piece are therefore not a mere sonification or visualisation of input data, but the result of processes driven by that data.

It is important to state that the system's interactions are only indirectly implemented. As Di Scipio puts it, interactions are the "by-product of carefully planned-out interdependencies among system components, [which] would allow in their turn to establish the overall system dynamics, upon contact with the external conditions" (Di Scipio, 2003). He also believes that this type of construction is akin to the mapping in living organisms that allows emergent behaviour to occur. The further coupling of Eno's laminar compositional system to elements of Di Scipio's ecosystemic design increases the complexity of the interactions and further enhances the possibility of emergent musical behaviour (Collis and Pickles 2016).

8.2 Utilising Stafford Beer's VSM as a basis for real-time composition

Self-regulation in musical systems is rarely considered, as generally, the composer is seen as the sole governing mechanism, author, and arbiter of the work of music. This is often the case even in works of music that utilise systemic processes or technologies and appear apposite for autopoietic conjecture. However, when a composer views technology as an equal partner in the compositional process, no one entity, be it human or machine, is solely in control of the compositional outcome, therefore the issue of how a piece regulates itself to produce a desirable outcome becomes a concern. In many real-time compositional paradigms, human, machine, and environment are at play within the music-making process and the complexity of the interactions also becomes a design consideration (Eigenfeldt, 2011). Thus, where self-regulation of an "exceedingly complex system" (Beer, 1994) is an issue it becomes useful to relate these matters to system models, in order to gain a better understanding of how self-regulation and autopoiesis may arise. The cybernetician Stafford Beer's Viable Systems Model (VSM) is a representation of the functioning of the human nervous system. It was designed to demonstrate how a system may self-regulate and remain stable despite complex external conditions. Beer reasoned that this model might be applied to any number of human systems to assist in their smooth running and self-regulation, thus reducing the need for managerial oversight or interference (Beer, 1994).

The musical works *Sin-Plexus* (2013), with Daren Pickles (composer) and Nicholas Clifford (animator) and The Beast (2015), Daren Pickles (composer) Glenn Noble (Theatre Director), explore a number of cybernetic themes and utilise Beer's Viable Systems Model as a framework for approaching real-time composition. The impetus for these pieces arose from the desire to create a works of organised sound utilising cybernetic means. Thus, the very simplest of initial starting conditions was desired in order to demonstrate the dynamics of the cybernetic system at play within the composition. The composer Robert Ashley states that feedback is "the only sound that is intrinsic to electronic music" (Ashley in Holmes, 2002). Feedback was therefore chosen as a non-divisible sound element, an innate building block with which to construct the sound world. The concept of feedback is also a founding principle of the science of cybernetics (Wiener, 1948). Feedback can either be positive (amplifying – as is the case with audio feedback), or negative (dampening – used as a mechanism of control in electronic, mechanical, or biological systems). Positive and negative feedback may be utilised so that a system may achieve homeostasis, a state of self-sustaining equilibrium in which positive feedback mechanisms amplify and enhance deficient areas, while negative feedback dampens and controls overactive parts. This homeostatic mechanism is at play within all living systems as they attempt to find an equilibrial balance with their environment (Beer, 1994).

Beer's 1972 book, *Brain of The Firm*, examines how models of living systems may be applied to human enterprises. The book was a formative influence on the musician and record producer, Brian Eno. Eno utilised cybernetic principles gleaned from Beer's book to produce compositional systems, which have assisted and defined his recorded output throughout his career.

Although it is clear from Eno's essay, *Generating and Organizing Variety in the Arts* (Eno, 1976) that Eno has a comprehensive grasp of basic cybernetic principles and that he used cybernetic ideas as the foundation of a number of his most important compositions (Whittaker, 2003), it is also clear that his work does not fully exploit the models and ideas put forward in Beer's *Brain of The Firm* (Beer, 1972). In interview, Eno discloses that he has not read widely on the subject of cybernetic theory, but that he has read and re-read *BOTF* many times and that this book forms the basis of his understanding in this area (Whittaker, 2003). It is also notable that Eno has utilised quotations and ideas from the book many times in interview and within his own work and writings,[31] but that the extent of Eno's extrapolation only appears to extend to part one of the book (Chapters 1 – 6). The first part of the book is an introduction to cybernetic theory, written in Beer's idiosyncratic and charismatic style, covering topics such as feedback, elements of information theory, heuristics, and autopoiesis. However, Eno has never written, discussed, or implemented the mainstay of the subsequent theoretical content in *BOTF*, namely the Viable System Model. For the purposes of preparatory research for *Sin-Plexus* (2013) and *The Beast* (2015), a further extrapolation is made of the ideas Beer espouses in *BOTF*. Continuing where Eno left off, this chapter aims at furthering understanding of the Viable Systems Model, with the purpose of applying it in musical works.

Beer's Viable Systems Model is a facsimile of the functioning of the human nervous system and the body's major organs. Beer uses this metaphor to map this functionality onto the workings of commercial business enterprises (hence the title of his book, *Brain* of the *Firm*). Beer states: "cybernetics is actually done by comparing models of complex systems with each other, and seeking the control features which appear common to them all" (Beer 1994). Furthermore, the eminent cybernetician Gordon Pask defines cybernetics as "the science of defensible metaphors" (Foerster, 1992). So we may deduce that cyberneticians are seeking a meta-language of control that can be developed and applied in the design of analogous viable systems. Beer reasons that to be useful to human endeavours, effective systems must be utilised in this type of comparative analysis. Systems like animal ecologies are attractive as they demonstrate structural control principles that do not require an overall controller. They simply work by the balanced interaction of all the system's parts. However, this system is too unpredictable and open to catastrophic uncertainties (drought, famine, earthquake, etc.). They can also be very slow to react to stimulus because they are not self-aware. Artificial kinds of ecologies, such as economic systems, are more attractive, as they contain many more self-aware elements. However, the most successful, self-aware systems known to us are living organisms, and in particular the human body, which is highly effective at reacting to complex variety while maintaining internal stability (Beer 1994).

[31] Examples of which can be found in the chapter 6.2 in this thesis

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Fig. 33. Beer's 'Model of a Viable System': Two dimensions of neurophysiological control – the main vertical command system (somatic) and the sympathetic and parasympathetic systems (automatic) (Beer, 1994)

In Figure 33 (above) we can see the subdivision of some of the body's systematic processes and an outline of the command and control structure. Here, subsystems that perform automatic functions can operate autonomously from the central command axis and, indeed, can 'talk' to each other informally and separately from the central command axis. They are linked by 'sympathetic trunks', which run parallel to the central command axis. These subsystem chains govern the stability of the internal environment; they are feedback integrators and regulators (Beer 1994). There are two control systems at work here: the 'sympathetic nervous system' (which equates in Beer's metaphor to middle management), and the 'parasympathetic nervous system' (senior management). These controvert each other, often performing contradictive forms of control on the same organ. The sympathetic system runs on adrenalin, while the parasympathetic runs on another set of chemical impulses (cholinergic). These impulses have differing effects on different organs of the body, but one will act as a stimulator, while the other acts as an inhibitor. In this way, one system 'checks' the other and stability is achieved. So the automatic functions of the body have two 'masters'. However, the parasympathetic system has a much larger connection to the brain and is able to enact conscious decisions. An example of this functionality would be the operation of the respiratory system, which operates automatically, but can respond to signals from higher up the command chain (e.g. Hold Breath).

Fig. 34 The automatic system of a firm having subsidiaries A, B, C and D (Beer, 1994)

Figure 34 (above) demonstrates Beer's extrapolation of this neurophysiological model and its application in the modelling of a business enterprise. Here, each subsystem (1 through 5, and A to D) performs a different function within the enterprise. Subsidiaries A to D represent factories or manufacturing plants that directly engage with the outside environment. They deal with taking orders, manufacturing goods or services, and directly interfacing with the external environment in physically responding to demand. System 1 is responsible for the control of these subsidiaries; it provides the local management tools specific to each subsidiary. System 2 is an automated regulatory centre, which provides a local interaction between System 1 and its subsidiaries. This interconnection serves to regulate System 1 and its subsidiaries and acts as an interface with System 3. System 2 prevents uncontrolled oscillations between the divisions and is designed to be automatic and therefore fast in response to changes in the environment. System 3 performs the function of an operations directorate, overseeing the automatic functions of Systems 1 and 2, but providing the mechanisms and ability to override the automatic functioning should the need arise (for example, closing production in an unproductive division). It provides an interface between the 'conscious' decision-making of the higher board level and the automatic functioning of the lower production levels. System 4 is the Development Directorate; it acts as the company's 'eyes and ears' and is able to recognise changes and patterns in the external environment. The information generated by System 4 feeds the highest level of decision-making. It also contains a map or model of the organism. System 5 takes decisions based on these perceptions. It is in effect senior management. System 5 is able to contain a representation of the sensory and motor information of the outside world generated by system 4. These two types of information (motor and sensory) are connected in system 5 in a 'sensorium', which demonstrates an Ashby-type self-returning homeostasis. And thus, the homeostatic loop between sensation and action, between affect and effect is closed. System 5 attempts at all times, with the service of System 4, to adjust its output to its latest input, based on the prognosis, which the input sensorium is able to generate by rapid time simulation. This is known as 'foresight' (Beer, 1994).

The idea of systemic recursivity is also central to Beer's model; in terms of command and control, each subsystem is systemically similar or identical, despite them performing differing physical functions. Subsystems may exist in series or parallel or (more integrally) in recursive hierarchies. For example, Subsystem 1 is incorporated into and forms part of Subsystem 2, which in turn forms part of System 3, and so on. At the top of this hierarchical chain sits the brain. Each subsystem may have its own 'language' of control but each is systematically the same and fundamentally interlinked. However, it is important to note that command and control does not just reside in the brain, but is distributed throughout the system, so that the smallest of changes or decisions made at the 'bottom' of the hierarchical chain can effect the 'highest' command and control mechanisms as well as vice versa. In management terms, the 'inline' chain of command means that each element in the chain has responsibility and is capable of making autonomous adjustments. It is also noteworthy that while the bodily system is self-contained, it also resides in greater systemic hierarchies, which constitute the outside environment. They also extend *down* into the realm of subatomic particles. This type of non-hierarchical command structure, involved in conscious decision-making, is also postulated in the book *I Am a Strange Loop* (Hofstadter, 2007) by the Professor of Cognitive Science, Douglas Hofstadter.

Beer's model of a viable system is an extrapolation of the control principles found in the human body, but it is also prescriptive, as a model of best practice for command and control structures within an enterprise. It is possible to apply this model to other organisational structures, as Beer does in Part 4 of this book, which is an application of his viable system model to the running of the Allende government in Chile from 1971 to 1972. Unfortunately, project *Cybersyn* was never fully realised due to the toppling of the Allende government by a military coup-d'état in October 1972. However, the documentation of that implementation is provided in the book in some detail (Beer, 1994).

For the purpose of the adaptation of Beer's model for use in real-time composition, a further extrapolation and application of the 'Viable Model' to a musical system is undertaken here:

Fig. 35. The application of Beer's 'Model of a Viable System' to a real-time musical composition

Beer states that a viable, self-generating system requires an energy input and an internal system that can achieve homeostasis (stability). The system achieves homeostasis via internal and external feedback mechanisms that either 'avoid' or 'reinforce' stimulus. This decision is decided by a transfer function (switch) that adheres to the organism's criterion of stability (this can be very precise, as in an algorithm), or for more complex, adaptive tasks, an heuristic is required (Beer 1994).

Within the above application of Beer's model (Fig. 35), subsidiaries A, B and C represent sound elements or transducers that interface with the environment. These are the components within the system that create or capture sound (providing the initial input), for example, a microphone, an electronic oscillator, or musician (the initial energy input may be derived from the external sound world, or be internally created). System 1 represents the physical control mechanisms: audio effects that can manipulate, modulate and affect the sounds generated by the subsidiaries. System 2 is a regulation system that utilises the control functions of System 1, to amplify or dampen signals. System 2 regulates to a predestined 'criterion of stability', which by the control mechanisms of amplifying or dampening signals, will generate a 'stable' sound world.

Systems 1 and 2 and parts of System 3 are automated and can generate a constant soundscape. System 3 acts as an interface between the automated processes and the 'conscious' processes of a human composer or a computer capable of making 'viable' aesthetic decisions. System 3 may be a control surface or other such device that enables interaction. Systems 4 and 5 form the perception and enactment of aesthetic judgments within the system. They are based on the pattern recognition of System 4 and the perception of the effects of actions taken by System 5 on the external sound environment.

This model allows for the possibility that all elements in the system may be completely automated. However, in terms of producing viable compositions, the pattern recognition of System 4 would have to be highly developed and the criteria of System 5 would need a strong technological, epistemological and ontological basis from which to operate. Beer does outline some of the mathematical basis that might underlie such a system, but development in this area is beyond the current scope of this research.[32] It is therefore more consistent that Systems 1, 2 and 3 are wholly or partially automated and Systems 4 and 5 be controlled by human agency.

Amplification	**Dampening**
Equalisation	Equalisation
Distortion	Filter
Delay Lines/ Looping	Compression
Flange	Phase
Chorus	Gating
Auto Pan	Granular Effects
Granular Effects	Bit Reduction/ Downsampling
Bit Reduction/ Downsampling	Resonator Effects (in some implementations)
Resonator Effects	Volume
Reverb	
Volume	

Fig. 36. The classification and function of effects processing in achieving stability

It is also important to note that the classification and function of effects processing in achieving stability seen in Figure 36 (above) is made at the author's discretion and as such is knowingly open to criticism and further study. These concerns are not the issue of this chapter, which is not intending to provide a fully prescriptive implementation of Beer's Viable Model to musical composition, but to indicate the viability of the model mapping in practice and to indicate now this is done in the compositions in the subsequent chapters. Suffice to say that Beer's model demonstrates that cybernetic analogies can be useful in the design of musical composition systems, especially those that utilise electronic technologies, seek self-regulation, and require a meta-language beyond formal notation that speaks to what is common between human, machine and environment.

[32] Although Beer would have undoubtedly favored a biological computing approach, as Pickering outlines in Chapter Six of *The Cybernetic Brain*, "Stafford Beer, from the cybernetic factory to tantric yoga" (Pickering, 2011), in his real world implementation of the viable systems model in Allende's Chile in 1971-72, Systems 4 and 5 were envisioned largely as human-controlled (Beer, 1994).

8.3 *Sin-Plexus*

Please note that a recording of Sin-Plexus, the computer animation, recordings of rehearsal and development work and the Ableton Live session files can be found on the accompanying materials to this thesis.

8.3.1 Introduction

Sin-Plexus draws influence from a number of cybernetic themes, the primary focus being the cybernetic mechanism of feedback, both audibly and in control functionality, to facilitate musical composition. The initial musical inspiration came from feedback processes in Steve Reich's *Pendulum Music* (1968) and Robert Ashley's *The Wolfman* (1964), and a desire to reinterpret these ideas using modern computer technology. It was felt necessary to conceptually rid the composition of any extraneous affectation, similar to Alvin Lucier's assertion that his main activity in composition is to eliminate all possibilities within a piece, leaving only the essential components (Harder and Rusche, 2013). In this instance, Lucier's method of elimination for creative purposes pertained to using audio feedback as the sole sound source for the piece.

In order to conceptualise how flows of information within the cybernetic musical system might be managed, Stafford Beer's VSM (Beer, 1972) was adapted from its original conception as a cybernetic management model and implemented as a control framework for the composition. Use of this model offered the conceptual possibility of using methods of *variety* (in Ashby's terms, Ashby 1952), suppression of unwanted 'noise', and the use of variety enhancers for desired signals. Certain DSP functions were utilised to perform the suppression and amplification controls. Di Scipio's conception of the DSP functions utilised in his Audible Eco-Systemic Interface project (AESI) was used as a theoretical guide to the type of DSP that would be viable in enhancement or suppression of wanted or unwanted sound elements (Di Scipio, 2003). A dissemination of what may constitute as variety enhancing and variety reducing DSP can be found in *Fig. 36* in the previous sub chapter (Chapter 8.2). However, the proprietary DSP used by Di Scipio was not a possibility in this instance and therefore a set of standard manufacturers' audio effects in the Ableton Live[33], MAX for Live,[34] and Native Instruments[35]software packages were utilised to provide similar functionality. Another structural design choice that differed from Di Scipio's AESI was the utilisation of loops of audio, recorded during the performance and saved in the memory of the DAW as a basis for the structure of the composition. In the AESI, sound passes directly through the audio buffer and is manipulated in real time with little storage to memory. However, Brian Eno's tape-looped compositions, especially *Discreet Music* (1975) were a more apposite model for *Sin-Plexus* in so much as the non-contiguous, laminar structure of the tape-loops was highly analogous to the loops of recorded audio in Ableton live. Furthermore, the use of recorded loops also enabled the potential use of time manipulation, which is not possible in the same way as in the AESI; the choice of loops that are played in a

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33 https://www ableton.com/en/live/

34 https://www ableton.com/en/live/max-for-live/

35 https://www.native-instruments.com/en/

performance of *Sin-Plexus* means that musical motifs or sounds from a previous time in the performance can be repeated when desired (instead of the more arbitrary use of delay in the AEIS).

Automation, and in particular the extent to which the computer was able to adapt to its own internal state in respect to external conditions, was also a consideration; Some DSP automation was achieved via MIDI information sent from Max for Live plug-ins but this aspect was underdeveloped in the final implementation due to processing constants. However, given the current technology available to the composer, this may be solved in future iterations via the use of two computers, one to process the audio functions and one to process the MIDI control functions. Further research in this area is underway.

8.3.2 The Integration of Stafford Beer's VSM into Compositional Design

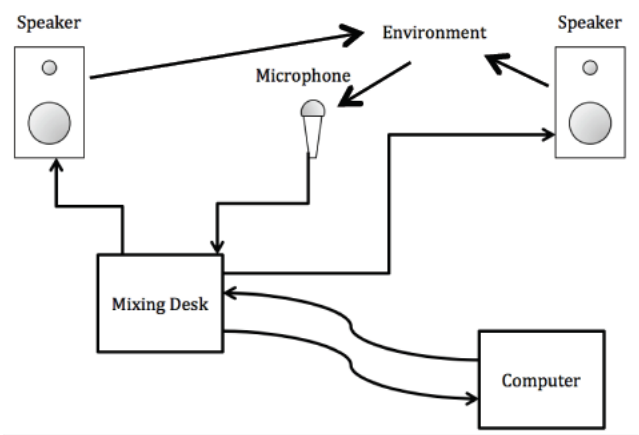

Fig. 37. Audio signal flow of Sin-Plexus Performance.

In practice, *Sin-Plexus* takes the form of a live performance incorporating microphones, mixing desks, a laptop running the Ableton Live software, and other aforementioned plug-ins (see below for a full description). The soundscape produced plays in conjunction with an accompanying interactive computer-animated video made using the Unity game engine[36].

As we may see from the above diagram, a microphone is placed near the playback speaker and an audio feedback loop is generated by riding the microphone input gain on the mixing desk. This input is analogous to the transduction systems A, B or C in *Fig. 35, The application of Beer's 'Model of a Viable System' to a real-time musical composition*, In the previous subchapter (Chapter 8.2, P-156). The frequency of the feedback tone may be controlled via the mixing desk equalisation. As the piece unfolds it can become excessively noise-like and therefore a low tone of between 60 and 100Hz is desirable as the initial starting tone. Choosing a simple, low frequency tone acts as a verity reducer, preventing exponential, runaway feedback howl. Moreover, with limited tonal variance at the beginning of the piece, the musical sound world can unfurl in an organic, controlled way, with compositional

36 https://unity3d.com

sensitivity. The environmental space also plays a major factor in the resultant feedback tone and therefore some 'tuning' of the feedback tone (moving the microphone differing distances from the speaker) may be required to gain the desired initial tone. The feedback tone is the first indication to the audience as to the mechanism of the systemic composition; i.e. that the entire piece is derived from feedback.

The performer makes choices about when to record the feedback tone. This recording is then looped in the DAW and the performer chooses when to play this looped material back into the environment. Each loop has a series of DSP processing effects acting upon it that alter the sound of the recorded loop. Some effects are designed to 'enhance' the signal and others are designed to 'dampen' and control the signal. This set of processes is signified in the VSM by System 1 (control procedures, in this case DSP effects) and System 2 (amplification and dampening control, in this case control information that operates the DSP effects), which can be seen in *Fig. 35* from the previous sub chapter (chapter 8.2, P-156). Each loop, with the addition of audio processing, is played back into the environment via the speakers and further loops of the resultant audio are captured creating further layering, density, and complexity in the soundscape. The performer carries out these operations via the computer keyboard and a MIDI control surface, this represented by System 3 of the VSM, 'Automation command' in *Fig. 35* in the previous sub chapter (chapter 8.2, P-156).

The perception and the choices made by the performer close the performance feedback loop and are represented by System 4 (composer's perception) and System 5 (composer's decisions) in *Fig. 35* (chapter 8.2, P-156).

The system is designed to create complexity, operating with multiple layered loops and DSP manipulations occurring in real time. Many of the parameters of the DSP effects are also automated. The composer "rides the dynamics" (Beer, 1994) of this system and attempts to push the performance towards an aesthetically pleasing outcome. However, the computer and the acoustic environment are also active agents in this process, meaning that no one agent in the human/machine/environment system is solely responsible for the artistic outcome; each has agency within the performance, and each is tied together in a system of feedback loops. It is also important to note that the work is ephemeral; its outcomes are unpredictable and different in each iteration.

8.3.3 Technological Compositional Structure

In a performance of *Sin-Plexus*, the signal from the microphone is fed into the computer soundcard via an auxiliary (aux) output on the mixing desk (see *Fig. 37*, above). The signal is recorded into individual audio tracks in the Ableton Live software running on the computer, in loops of approximately 10 seconds duration.

These audio loops can be seen on the left of the screen in *Fig. 38* (below). The software continuously plays around the 10-second loop and further loops are recorded onto subsequent tracks so that a laminar soundscape is formed. On the left of the screen the names of the individual can be seen (e.g. track 1) and to the left of the track name further functionality can be seen. For example in individual track panning, volume, muting and routing. At the top of this column of tracks we can see that they are grouped together (in Group 1, seen on the right of the screen in *Fig. 38*). This grouping relates to the 'malleable' and 'automated' plug-in sets which are be examined below (group 1= 'malleable' audio tracks and group 2='automated'.

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Fig. 38. Screen shot of Ableton Live software during a performance of Sin-Plexus.

There are two distinct types of audio tracks that have been designed to be utilised in the performance of Sin-Plexus: a) those that have been designed to be utilised for real time manipulation by a performer, and which have been denoted as 'malleable' audio tracks as can be seen below in *Fig. 39* (Below) and b) those that have been designed to manipulate the incoming audio with automated DSP plug-ins, as can be seen in *Fig. 40* (Below).

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Fig.39. Example of plug-ins on 'malleable' audio tracks

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Fig.40. Examples of plug-ins on 'automated' audio tracks

What follows is a brief description of the DSP plug-ins to be found on each type of audio track, their function and their basic use within the composition. It should be made clear that not all these plug-ins are employed at any one time or manipulated uniformly across each of the tracks. Rather, decisions are made in real time by the performer as to which plug-ins are to be engaged and when, and how they are to be manipulated based on the sound being emitted by the speakers. The plug-ins appear in the order they are placed in the audio chain and are as follows:

a) The plug-ins on the 'malleable' audio tracks (*Fig. 39*, above) are all generic plug-ins to be found in the Ableton Live Software: 1) Saturator: this is a simple gain/distortion effect, used to increase the volume on the incoming signal where necessary and on occasion to produce harmonic distortion. 2) Gate: this is used to cut out unwanted quiet passages. If the signal has repeated loud and quiet sections, or a succession of staccato transients, the gate may act to exaggerate the rhythmic qualities. 3) Dual Shifters: this effect is the combination of 2 pitch shifters set at an octave above and below the original signal; it also incorporates delay. This effect is used to enhance the incoming signal, adding depth and higher harmonics when required. 4) Utility: this is a further gain stage, should the signal require additional volume. 5) Resonators: this effect is a series of feedback delays, which oscillate at set pitches to create tonal harmonics, which can be mixed in with the original signal. In compositional use, this may add harmonic content to a non-pitched input, or create resonant chords or harmonies to augment pitched content. 6) Frequency Shifter: this effect alters the pitch of an input signal allowing for rapid and fluid pitch alteration, which, when used on a feedback tone, is akin to a Theremin-type sound. It also has the capacity to pitch shift in ring modulation mode, which has an audible effect reminiscent of changing the channel on a shortwave or AM radio, or indeed akin to the sound of the Ring Modulators that Louis Barron employed in the soundtrack to *Forbidden Planet*. 7) Audio Filter: this is employed as a low pass or high pass filter to reduce or (via the addition of resonance) to boost higher harmonics. It also has an automated LFO, which may modulate the cut-off point and create rhythmic filter sweeping effects. 8) Auto Pan: this effect has an automated LFO, which may modulate the signal rhythmically between the left and right speakers, or the effect may be set to mono mode to create more direct rhythmic tremolo effects. Changing the LFO rate will determine the speed of the amplitude modulation pulses. 9) Beat Repeat: this effect samples small snippets of audio to repeat in succession. This repetition may occur on beats of a bar or at randomised intervals. It is used compositionally to create sporadic rhythmic punctuations. 10) Grain Delay: in terms of *Sin-Plexus*, this effect is used more than any other to 'play' the pitch of the incoming audio. There is an x/y controller, with frequency on the x-axis and pitch on the y-axis, and this is manipulated in real time to produce a playable pitch-orientated audio track. In addition, the signal may be broken into dispersed grains by increasing the 'feedback' and 'spray' settings.

The plug-ins on the automated tracks (*Fig. 40*, above) are made by the Pluggo software company and are MAX for Live plug-ins: b) the plug-in chain is as follows: 1) Wheat: this is a granular plug-in with many of the usual controls associated with granular processing, such as grain speed, crossfade, length and pitch. It also has an LFO, which, when employed in conjunction with the feedback tone and appropriate granular settings, creates pitch sweeps with strong rhythmic noise-like qualities. 2) Feedback Network: this effect creates random feedback times of varying pitches and amplitude tones. It also has a delay line and when used in conjunction with a recorded feedback tone is reminiscent of Robert Ashley's *The Wolfman* (1964) and the

Barron's soundtrack to *Forbidden Planet* (1956). 3) Harmonic Filter: this effect is an automated 25-band graphic equalizer. The automation of each individual frequency band is controlled by a cellular automata algorithm. 4) Dit Dit Dah: this is a 32-step sequencing effect that chops the audio into 32 individual triggered envelopes, which loop in a BPM sequence defined by the DAW. Individual envelopes can be turned on or off to create a stuttering staccato rhythm. 5) Audio Rate Pan: this is a sophisticated auto panner, which synchs to the audio rate and allows you to change the depth and frequency of auto panning. 6) Auto Pan: this is the same plug-in as used on the malleable audio track, but here it is used only to rhythmically chop up the sound when required.

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Fig.41. The Native Instruments Travelizer granular effect processor.

In addition to the automated tracks, which predominantly contain automated effects designed by the company Pluggo, there are 3 further audio tracks. Each contains a granular effects processor made by Native Instruments and known as the Travelizer (*Fig. 41* above), into which recorded audio can be loaded during a performance. This effects processor contains standard granular controls including the likes of grain speed, crossfade, and, length, but also automated pitch and grain position, which create movement and variety. It also contains a resonator, filter, delay and an x/y controller, which makes these parameters very accessible and mutable in real-time performance.

The ratio of manual and automated effects were evenly distributed with the environmental factors at play within the composition, in order to reflect a balanced, human/machine/environment structure. Many granular plug-ins were also chosen to reflect Di Scipio's technological compositional choices.

8.3.4 Computer Graphics

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Fig.42. Two photographs of live performances of Sin-Plexus demonstrating the projection of computer graphics: ICMC, Aug. 2013, Perth, Australia (Left), Klangland Festival, April 2014, Kassel, Germany.

The emergent aesthetic properties of the soundscape form the artistic impetus for the accompanying computer graphics, which were designed by computer animator Nicholas Clifford. There was a desire to use the most basic graphic components, again to demonstrate the system at work within the composition. The overriding impression of the soundscape, particularly in the initial stages of the piece, is that the generated feedback tones are analogous to audible sine waves, which converge, overlap, and mutate into a complex web of interconnected sound elements. Thus the computer graphics utilise visual representations of sine and cosine waves that weave around each other to form a 3-D, circular, evolving knot that speeds up and slows down according to fluctuations in the sound amplitude of the piece. The computer animation was initially built in the Houdini computer animation software using the inputted equation: x=cos(t)*cos(t*time). The program was later adapted to be interactive for live performance using the Unity game engine. Here a performer may run the graphics in real time in conjunction with the music, and further direct the speed and movement of the graphics by touching an iPad screen. The combination of the audio and visual elements inspired the name of the piece: with 'sin' standing for sine waves, and plexus, meaning knot.

The purpose of the visual element was to further demonstrate, via cybernetic means, how organised sound and graphics might emerge from exceedingly small initial inputs to create a complex and evolving soundscape and visual accompaniment, a process that reflects the workings of living organisms and demonstrates how order may be derived from chaos.

8.3.5 Compositional Analysis

Conceptually, not unlike Di Scipio's AESI pieces, *Sin-Plexus* is a composition of interactions that is prefigured in software and hardware design by the composer and then enacted in a real-time performance. Each iteration is different in compositional structure, but falls within a set of aesthetic and acoustic parameters. Although the piece required conceptual forethought and design, particularly in how the audio feedback was to be created and controlled utilising the adapted model of Stafford Beer's VSM, a number of rehearsals were required before the initial performances of the piece before an audience. After initial tests by the composer, it was decided that extra variety and complexity would yield more multifaceted and stimulating results. To this end, another performer – my colleague at Coventry University and fellow electronic music composer, Nicholas Peters – was asked to assist in rehearsals and the live performance of the composition. Both performers used the Ableton Live software and DSP-processing in similar configurations as those described above.

In the first instance, rehearsals were required to test the validity of the VSM system for composition, as it was not initially known if the system would produce anything compositionally interesting in the time required for a live performance. In the second instance, rehearsals were used to hone the skills of the performers in using the software so that they might direct the performance into a more stimulating and viable set of pieces.

Although the design of the system was prefigured, some further rules were applied in the rehearsal stage to reinforce the cybernetic ethos during the performance. The main instance of such a rule being applied was for the performers to utilise the heuristic of 'boredom', as inspired by Gordon Pask. The application of this rule manifested in exactly the same way Pask had applied it in performances of the *Musicolour Machine* (Pask, 1971). Put simply, if an element of the soundscape is 'boring', the performers attempt to alter it by adjusting parameters of the DSP functions in real time, via a control-surface interface. However, as with the *Musicolour Machine*, the interface being utilised by the performers in *Sin-Plexus* is complex, with many available parameters; the audible soundscape, once established, is constantly evolving due to the continuous laminar feedback process. Therefore, it is not always apparent what element will affect the performance in a desirable way, leaving the performers to "ride the dynamics of the system" (Beer, 1972; Eno, 1975) in an attempt to push it in an aesthetically desirable direction.

Through the rehearsal process it was found that *Sin-Plexus* is a performance piece of indeterminate length. Various public performances have been realised of between 10 to 50 minutes in duration. However, rather than the work existing in a theoretical continuum in the mode of works by Eno or Di Scipio, *Sin-Plexus* has a definite starting point and an end point; the work unfolds over time, developing from one initial feedback tone into a complex web of interacting sound elements. The start point occurs when the system is first fed with energy and the end point arrives when the performers have exhausted the criterion of stability. This compositional conception conforms to Kayn's statement that "the process of creation is integrated into the acoustic supersignal, and remains transparent. The control structure lies within the range of audibility, thereby forming an integral component of the generating process" (Kayn, 1977).

After two initial public performances of differing lengths, one for students and staff at a Coventry University lunchtime concert on 29th March, 2012, which was 50 minutes in length, and the other at the Noisefloor festival at Stafford University in May 2012, which was 25 minutes in length, it was decided to enter the piece for the International Computer Music Conference in Perth, Australia, in August 2013. For a successful submission, the piece had to be constrained to 10 minutes or less. This was a rather difficult task, as the length of the piece had been conceived as being determined by the amount of initial energy input into the system, how the resultant manipulated audio interacted with the acoustic environment over time, and the boredom threshold of the performers. Conceptually, therefore, it rather went against the sprit of the piece to have to constrain it to a time limit and possibly some kind of score in order to ensure that enough sonic variety and dynamic variance were achieved within the time frame. Nonetheless, it was felt by the composer that it was worth sacrificing some of the conceptual framework in order that a wider audience could hear the piece. To this end, rehearsals began to attempt to achieve a strict 10-minute version of the piece, without forgoing the organic nature of the composition and maintaining the sonic variance achieved in previous rehearsals and performances of the piece.

Fig.43. Score for 10-minute version of Sin-Plexus for performance at ICMC 2013

In rehearsal it was found that the most expedient way to achieve a 10-minute version of the piece was to simply use a stopwatch and for the performers to follow a simple score denoting when the piece should achieve complexity and dynamic peeks (*Fig. 43*, above) Through the prior rehearsal and performance process, certain passages that had been easy to repeatedly achieve through manipulation appealed to the performers and it was felt that these should be included in the shortened version. A prime example of such a moment is to be found in the quiet passages that often followed a crescendo. These occurred after a full and complex soundscape had been achieved through the laminar feedback process and repeated sonic manipulations, and then the performers gradually reduced the volume of individual recorded tracks or removed them all together, leaving a complex but subdued organic soundscape. These passages represented a 'letting be' of the composition in these moments; very few DSP manipulations took place in these sections as the performers listened to the results rather than constantly reacting to the soundscape and attempting to push it in one direction or the other. These organic, gentle, and reflective moments often had an almost pastoral quality, reminiscent of Eno's work and sections from Roland Kayn's pieces, and it was felt that this aspect should be included in any definitive performance. Examples of this type of passage can be heard in D & N 6.1 (from 8'30") and in the recording of the 10-minute piece (from 7'00"). These can be seen as being represented in the score as occurring between minutes 4 and 6 (see accompanying audio material for this thesis).

After a number of rehearsals, which can be found in the supporting audio material to this thesis[37] the piece was performed and reconstituted until it adhered to the required 10-minute format, a final version of which was recorded for the ICMC submission.[38] While this is a successful piece in many respects it is problematic conceptually, since while it maintains many of the cybernetic precepts outlined in the compositional framework (chapter 7), it is nonetheless forced into a time-limited format and a somewhat repeatable status, rather than being allowed to evolve in a purely organic and truly ephemeral way. Suffice to say that while the 10-minute piece is perhaps representative of a more aesthetically idealised form of the piece, in compositional terms, it lacks the spontaneity and ephemerality of a truly cybernetic composition. However, it did fulfil its function of being heard by a wider audience of peers and it also served as the basis for the subsequent composition, *The Beast*, which is also considered within this thesis and which is seen by the composer as a more fully realised implementation of Beer's VSM in a musical composition.

8.3.6 Conclusion

To conclude, four further significant aspects in relation to cybernetic composition were found in the development of this piece. Firstly, even though the piece was significantly different in each iteration, it always conformed to a class of outcomes; it could be demonstrably recognised as the same piece of music. Thus a cybernetic precept was seen to work in practice through the embracing of heuristic design principles. Secondly, unlike the AEIS, minimal tuning to the environmental space was required. Here, the desire to rid the piece of any extraneous affectation appeared to produce an ease of operation that was initially unexpected. Thirdly, the audible complexity that resulted from such simple design precepts, the fact that at a certain point the piece "took on a life of its own" was an unexpected benefit of the system, allowing the performers to experience the "riding of the dynamics" of the system in a visceral way. Finally, the piece audibly shares many commonalities with the Barrons' *Forbidden Planet* (1956) soundtrack. While this was perhaps to be expected, as many similar technological ideas were being played out in the performance, this was an unexpected outcome for the performers that also appeared to demonstrate a common cybernetic compositional ethos with the Barrons' work.

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[37] see all versions of Sin-Plexus: D&N 1 – 7, 10 min piece, ICMC rehearsal & Berlin, In the Six Plexus Folder in the accompanying materials.

[38] see 10 min piece 1 & 2, In the Six Plexus Folder in the accompanying materials.

8.4 *The Beast*: Long-Form Improvisation, Feedback Loops and Cybernetic Music

Please note: Film of the performance of The Beast and its development in rehearsal can be found on the materials accompanying this thesis.

8.4.1 Introduction

The Beast utilises cybernetic music in a work of long-form improvisational theatre. In conjunction with supporting video extracts, this chapter explores a specific collaboration incorporating improvisational practices and audible performance ecosystems. There have been several public performances of the work, most notably at the Theatre and Performance Research Association conference at the University of Worcester in September 2015. The example included in this thesis was recorded in April 2016, at the Ellen Terry Theatre at Coventry University.

8.4.2 Rehearsal and Development

From a compositional standpoint, the technical construction of *The Beast* is identical to the one utilised in the *Sin-Plexus* piece. However, speech and the actors' movements on stage during the performance are used as sonic material from which the real-time composition is formed. This mirrors the use of speech by a number of cybernetic composers, including Alvin Lucier (*I am Sitting in a Room*, 1969) Herbert Brün (*Futility*, 1964), and Roland Kayn (*Cybernetics 1*, 1968). Another unexpected symmetry between this work and the work of a number of cybernetic composers in this thesis is that both Agostino Di Scipio and Gordon Pask had an overt interest in the creative possibilities of the theatre. We may also consider the Barrons' work in films and Kayn's extended performance happenings (Kayn, 1977a) to display a similar interest in acting and theatrical performance. Pask's theatrical learning machines, in particular, demonstrate this connection between cybernetics and theatrical performance. Perhaps this link to theatre is not as surprising as it might first seem, since these cyberneticians and composers were preoccupied after all with a performative view of the world and in the staging of ontological theatre. However, it is striking how this metaphor has spilled over into actual theatre in the case of several of the composers highlighted in this thesis. To directly reflect this ethos, the actors and composer of *The Beast* held the theme of 'ontological theatre' to be a central tenet in the development of the piece.

The form of the piece was developed in numerous rehearsals, with different iterations revealing different facets and performance possibilities. In keeping with the precepts of cybernetic music and long-form improvisation, the content of the performance was different in each iteration.

The materials accompanying this thesis include eight videos that document the rehearsal process that led to the formulation of the performance of *The Beast*.[39] The rehearsals took place over two days on the 23rd and 24th of July 2014, over a year

[39] See "The Beast-Rehearsals & Development" folder in *The Beast* Folder on the accompanying materials for this thesis.

before the first public performance. The rehearsals involved the author of this thesis and the co-creator of the piece, the actor Glenn Noble. In addition, two other members of Coventry University staff were involved in the rehearsals, the actor and Senior Lecturer in Theatre, Joff Chafer, and the dancer and Senior Lecturer in Dance, Katye Coe. Joff Chafer and Katie Coe also performed *The Beast* at the Theatre and Performance Research Association conference at the University of Worcester in September 2015. However, they were unable to take part in the April 2016 performance at the Ellen Terry Theatre at Coventry University. In this instance, the actor Jamie Greer took part, along with Glenn Noble and the current author.[40]

The video and sound in this recording are of poor quality and the recording was only intended to be used as a reference for the performers in subsequent rehearsals. Nonetheless, these recordings offer a valuable insight into the development of the piece and some elements of the artistic process that were involved. The videos will subsequently be referred to as the Rehearsal Videos, or RV1, RV2, etc. in order to distinguish them from the video of the public performance.

The rehearsals that were recorded are simply different iterations of the improvised piece, each lasting approximately 30 minutes, with some being slightly longer or shorter. Unlike the ICMC performance of *Sin-Plexus*, no stopwatch was used to define the length of the *The Beast* and no score was made. The length of the piece was purely defined by the performers' instincts.

What can be seen in these rehearsal tapes is an experimental 'working through'; an examination of different ways the piece might be performed. Distinctive considerations can be seen in each iteration, as certain aspects are tried and adopted for future iterations and other strategies are rejected. In the early iterations of the piece, the performers are evidently not clear about which parts of the performance to prioritise; music, dance, and acting are sometimes explored with equal priority and on other occasions one element is chosen to the exclusion of other forms. For example, music becomes the priority for all the performers at certain times in these early rehearsals. In the following examples, the performance becomes solely musical with little or no regard to other elements: RV1 (1'40"): rhythmic elements are explored; RV4 (16'20"): a choir is formed by looping the performers' voices[41].

Similarly, in the following examples, acting and spoken narrative become the primary focus of the piece: RV1 (9'00"): a sea captain's book narrative; RV2 (15'00") cataloguing: RV3 (4'20"): "you can see for miles"; RV3 (9'50"): planning a robbery. Similar phenomena occur for dance and movement arêtes. In the following examples only dance and movements are performed, to the exclusion of music or spoken narrative: RV1 (12'30"): pointing duet; RV2 (4'00"): planting seeds and pulling up plants; RV2 (6'30"): hand movements; RV3 (1'50"): lifting heavy objects.

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40 Again, see "The Beast-Rehearsals & Development" folder in *The Beast* Folder on the accompanying materials for this thesis.

41 Interestingly, although improvised and spontaneous on the part of the actors, this has a similar compositional form and aesthetic to Cardew's *The Great Learning, Paragraph 7* (1971).

As the pieces progress, however, elements become much more integrated. For example, a moment occurs in RV1 (5′00″) where movements and vocalisations build up into a complex rhythm. Here we can see movements and dance creating the musical sound track. Nonetheless, the performance becomes most successful when all elements – music, dance and acting – coalesce to form a coherent narrative scene. This usually does not occur until the midpoint of each of these rehearsals, when a number of prior elements combine to form a coherent whole. Examples of this type of autopoietic narrative can be found at the following points in the rehearsals: RV1 (6′45″): an underwater scene emerges; RV2 (9′40″): Neanderthal man's footprints; and RV3 (8′30″): butterfly collecting.

In the rehearsal videos it is possible to see that a 'stage' has been drawn on the floor using white masking tape. This was done deliberately in order to define when the performance would start and end. When the actors crossed this line into the space this signalled the start of the performance and, conversely, leaving this space denoted the end of the performance. It was felt that defining a threshold in this way heightened the ritualistic atmosphere we wished to evoke from the performance. The other signal for the beginning of the performance was the initial feedback tone generated to create material for the musical soundscape.[42]

A number of significant events that played a pivotal role in how the piece developed can be found in the rehearsal tapes. For example, at the beginning of RV2, problems occur in getting a low frequency feedback tone with the radio microphones. Attempts are made to find the best position for the actors to stand, in order to achieve the best initial feedback tone. Having a large-diaphragm condenser microphone positioned near to the speaker to create the initial feedback tone eventually solved this problem.

As the performances progressed it became natural to leave more gaps within the music to allow for speaking narratives to evolve and silences to be heard. This became an important device and appeared to precipitate a much more balanced and cohesive narrative. A very good example of this phenomenon can be found in RV3 (9′50″) where all the elements coalesce for a long period around a narrative about a robbery. Here we can hear that the music comes and goes in a natural rhythm, leaving silences for spoken-word narratives to develop and thus reinforce the scene's emotional content with music where necessary.

In RV4, with the introduction of the dancer, Katie Coe, the piece becomes much more dance orientated. There is a continuous movement flow to the piece that wasn't there previously. However, there is a loss of natural pauses (both in terms of music and of movement) in this version, which makes it hard for a spoken-word narrative to develop. Nonetheless, an interesting musical phenomenon occurs at 16′20″, where the performers start to hum and sing in tune to the electronically modulated sounds. These vocalisations are then looped and played back into the space and the performers again sing over this loop, and so on, until a multi-layered choir emerges. A reprise of this choir can be heard in RV5.

[42] This is discussed in more detail on page 173 of this chapter

In RV7, the emphasis is on experimenting with sampling and playing back vocal narratives and phrases into the performance space. This precipitated the performance becoming much more oriented toward recollecting and acting out memories. At RV7 (7'20"), we can see Glenn recalling childhood memories of riding his BMX bike, a theme that is revisited in the public performance in the Ellen Terry Theatre in April 2016[43]. However, in this iteration (RV7, 7'20"), Glenn recounts and acts out a very moving true story of a boy he knew who died after cycling off the end of a pier. Performing this iteration crystallised the notion that this method of replaying voices from a previous time in the performance had a powerful effect on enabling the performers to recall memories and that this interleaving of remembered narratives, accompanied by the music, formed an evocative and commanding performance piece. At the end of the piece in VR7 (26'30") and continuing onto VR8, the performers discuss the implications of this performance, the memories that were evoked, and the emotional darkness at the heart of the piece. There is also a discussion of the implications of having more or fewer performers.

Two aesthetic consequences of the piece emerged that had not been considered prior to the initial rehearsals. Firstly, that the role of replaying snippets of the actors' speech back into the performance space, sometimes several minutes after they were initially spoken, had unexpected implications in forming the overall narrative arc of the piece. These vocal audio snippets would often serve to link themes from previous scenes into present scenes within a performance, so that all the minor narratives appeared to be interlinked in an overarching performance narrative. Furthermore, these disembodied voices in space evoked filmic, *non-simultaneous*, sonic flashbacks (Bordwell and Thompson, 1985), where characters in a film might recall a memory. Consequently, in the performance of the piece, the actors' improvised narratives often explored themes surrounding memory and remembering. This is a prime example of the feedback mechanism between the cybernetic composition and the improvising actors working symbiotically to create self-referential, autopoietic structures from emergent properties.

Secondly, and perhaps rather unsurprisingly – since the performance utilised the same compositional system as *Sin-Plexus* – the piece was again aesthetically similar to the soundscapes of *Forbidden Planet* (1956). In this instance, the interesting facet of this similarity was that the soundscape not only provided a musical mood for the actors to react to, but also sound effects that might link to an actor's actions, or invoke facets of an environmental space for them to inhabit.

8.4.3 Theoretical Starting Points in the Development of the Piece

In the context of this performance, cybernetic theory is used to inform process and understand how emergent behaviours and autopoietic narratives may be formed. One of its primary concerns of cybernetics is the study of information flows between components in a system and how this may lead to emergent behaviours. The concept of feedback is a crucial component in understanding how information can coalesce into organised systems and form autopoietic entities; from the cybernetic viewpoint, we may model the world as a system or environment that has a number of agents

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[43] See "The Beast-Full Performance" Video (6'50" & 15'40") in *The Beast* Folder on the accompanying materials for this thesis.

acting upon it or within it. This may be a simple mechanical agent, such as a thermostat, or an exceedingly complex one such as a human being. If an agent is capable of registering changes within the environment and acting upon them, it can be said that it receives feedback from the environment and is able to adapt its own behaviour to it. Thus a feedback loop is established between the agent and its environment, and this may continue proliferating in an on-going dance of agency between all the components of a system.

The name cybernetics is derived from the Greek kybernetes, which means 'steersman'. In the case of this performance, steersmanship may be seen as a critical metaphor for the actors to adopt as they take in feedback and adjust internal parameters to adapt their performance to form emergent narratives. In the human/ machine/ environment paradigm of the performance, one in which no one entity has overall control, steersmanship becomes a viable strategy, one which recognises the limits to agency but at the same time derives the ability to ride the dynamics of the system and make attempts to push it in the direction one may wish it to go.

8.4.4 Description and Evaluation of Performance

These ideas are reflected in the performance in several ways: the work begins with an audible feedback tone, generated by driving the input gain of microphones placed around the room and radio microphones worn by the performers. This feedback tone is recorded into the computer and manipulated by a performer using digital signal-processing software. The feedback tone is used as a basis from which to create sound and music, which is subsequently fed back into the space for the actors to hear and react to. As the performance unfolds, the words spoken by the actors are also recorded, adapted, and manipulated, and the resultant audio is played into the space in an ongoing feedback loop. The sound and speech recorded into the computer is captured in loops of approximately 20 seconds duration, which are layered on top of one another to create a complex web of looped audio material.[44] The composer manipulates the audio in real time and determines what may be manipulated and what may be fed back into the environment. For example, unaltered snippets of speech may recycled from a previous time in the performance, recalling a memory or previous trope. At other times, a complex layering of adapted musical sounds may be heard, providing an underlying musical mood, or an emotionally evocative springboard for the actors.

44 See Sin-Plexus, chapter 8.3, for a complete description of this technical process

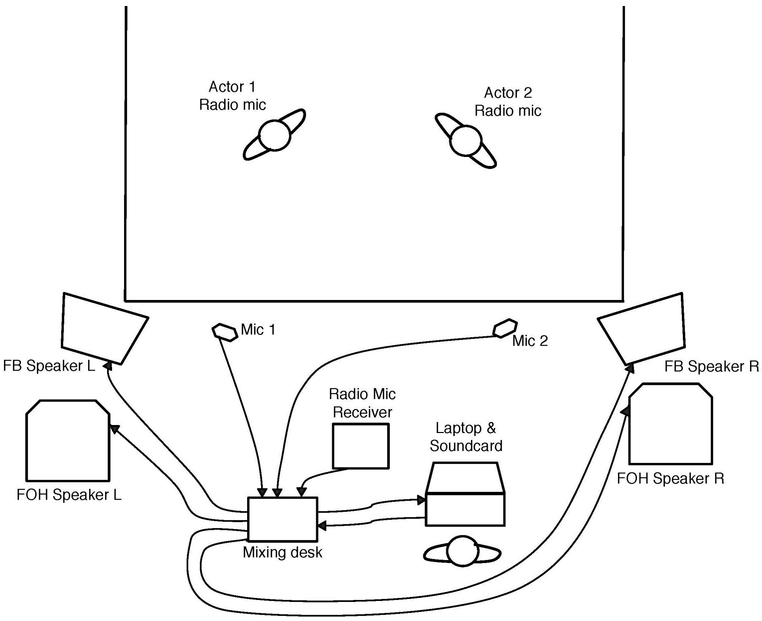

Fig. 44. Technical Performance Set-Up for The Beast

What follows is an evaluation of the performance from the actors' perspective. Here, the actor Glenn Noble describes the process and events that take place during the performance, making direct reference to 3 video clips of the performance that accompany this thesis[45].

8.4.4.a. In Reference to Video Clip 1:

> To signal a beginning, entrances are made into the performance space, which, for the purposes of our improvisation, we focus upon as "a kind of liminal space, where *not knowing* is […] sought, explored and savoured [...] where getting lost is constructively deployed alongside wonder, secrets and play" (Fisher and Fortnum, 2007). This strategy is important to the work, as unlike other types of long-form theatre improvisation, there are no pre-planned structures or frames within which to fit the improvisation, and there are certainly no audience suggestions or prompts to 'prove' the improvisational practice in operation. Once in the space, an explicit taking and shaping, moulding and manipulating of space is instigated. Discovery is demonstrated and emphasised, as initial, mimed vignettes become apparent. This discovery leads to the establishment of early narrative contexts and the performativity or self-reflexivity of the live event is reflected in the playful connection with the audience. In this way, we invite the audience to engage with us as complicit parts of the live event – as essential parts of the simple system.
>
> Each performer echoes this same entrance principle and a process of physical agreement and interaction begins. A simple chain of mantras operates – 'mirroring, heightening, exploring and transformation' – and this is the mechanism of the generative process from an improvisational perspective.

45 See "The Beast- 3 Video Clips Referenced in Thesis" Video's in *The Beast* Folder on the accompanying materials for this thesis.

All of these separate mantras are creative strategies in themselves and they find their origins in Viola Spolin's work, first outlined in her book, *Improvisation for the Theater*, in 1963. This practice specifically calls for an interaction with, and transformation of, found 'space-objects', as a route to procedural memory, personal significance, and a reconnecting with lived experiences to elicit spontaneous context. This particular embodied process gradually leads to dialogue, recollected memories, narration, and confessional elements, which are captured and shaped by the sonic artist utilising audio software. We make explicit the role that Daren plays as an equal collaborative improviser, rather than a lowly 'sound technician', not only by his presence within the performance area, but by ensuring that he also has a performative 'arête'-style entrance, or an "*and this is me*" for the audience at the start.

8.4.4.b. In Reference to Video Clip 2:

The particularity of our collaboration explores why this specific sound improvisation has had the effect of eliciting autobiographical material – narratives from memory and personal reminiscence that are shared, embellished, and fictionalised. The practice explicitly relies upon the body connecting with procedural memory to offer instant context to the improviser, but the effect of feeding back voices and reincorporating spoken content from minutes earlier has created a particular performance environment for this exploration of lived narratives. Around ten minutes into the work, the space is now full of pathways and areas of significance relating to discovered spatial context: a bicycle rider; door-to-door police enquiries; a father and daughter preparing to leave the house on the morning of her wedding; a photograph; a preoccupation with a hand signifying some terrible act; a picket line and brazier, etc. These fragments establish separate narratives threads, and reincorporation, transformation and montage are beginning to happen – the work is starting to become self-referential.

8.4.4.c. In Reference to Video Clip 3:

Around twenty-five minutes into the work and the separate narrative threads begin to tie together through reincorporation, or continued feedback. With the sense of the closed system self-referring and self-constructing, of tying itself together, an autopoietic system or narrative becomes more apparent to the improvisers and audience, themselves part of the system, who provide their own 'feedback' within the system, be that laughter, applause, or the close engagement and palpable 'pin-drop' silences around dramatic discoveries.

(Glenn Noble in Noble, G and Pickles, D, 2016)

8.4.5 The Further Influence of Theory on the development of the piece

It is important to note that the musical software system that facilitates this soundscape is designed to create complexity and operates with multiple layered loops and sonic manipulations occurring in real time. Many of the procedures that create this soundscape are also automated within the software. This means that the human performer cannot direct the performance solely in the way that he or she may wish to[46]. That is to say that the computer is also an active agent and partner in the creative process. Furthermore, no one agent, whether it be man, machine, or environment, is responsible for the creation of the performance; all agents interact in a non-hierarchical way, each having agency within the performance.

The complexity that this represents, coupled with the ever-evolving performance of the actors reacting to the proliferating soundscape, creates an unpredictable performance outcome, one in which there are set parameters that are designed to create a performance that will fall within a 'class of goals', but which is different in each iteration, complex in narrative and unpredictable in outcome.

From the cybernetic viewpoint it is important to emphasise this type of complexity; for the cybernetician, exceedingly complex systems are 'black boxes' that we can never fully comprehend just by studying their inner components (the human brain is a good example of such a system). However, we may gain a great deal of insight by studying how these black boxes interact with the world, their range of behaviours, abilities, and idiosyncrasies. From the cybernetic perspective, the world is not a series of set truths about things that lay waiting to be unearthed, but rather one in which meaning is made via interaction; a complex system's emergent behaviour can only be discovered in a performative context. Similarly, the meaning and unfolding of a cybernetic performance can only be discovered through interaction in a performative context. It is important to note that this is a distinctly non-modern ontology, which is not centred on Cartesian thought, hierarchical worldviews, or epistemologies.

At their best, cybernetic art projects stage for us what the philosopher of science Andrew Pickering calls 'ontological theatre'. This describes how cybernetic machines or systems 'act out' this non-modern, non-hierarchical worldview. Pickering states that cybernetic projects stage ontological theatre for us in two senses: Firstly, as an aid to our ontological imagination, helping us to consider a different understanding of our being in the world and as an invitation to think that the world in general might operate in such a way. Secondly, cybernetic projects are examples of what might happen in practice if we adopt this non-modern imagining of the world and enact a performative ontology (Pickering, 2011).

Another important aspect to consider within this piece of work is the setting in which transformation takes place. When considering the work's staging, the processes of rites and rituals were important touchstones in its inception. The mantras previously referred to (by Glenn Noble, above) are ritual-like – essential to

46 See chapter 8.3: Sin-Plexus, for a full description of the software utilised in the performance.

the causality of the process. This was in particular reference to considering how the meaning-making process operated in this kind of *ex nihilo* performance.

Pragmatic philosophy, which shares many commonalities with cybernetics, in particular the performative ontology, is helpful when considering these questions. Marshall McLuhan's theory of the 'post-literate society' points toward a way of viewing this type of improvisational practice that incorporates technology. McLuhan states that there are three human ages: the pre-literate society, the literate, and the post-literate (the society in which he claims we now dwell). Different types of technologies and how they are used define these epochs.

To recap this philosophy: In the pre-literate society means (or technologies) and ends (their uses) are immediate and inseparable. Tools are important and intimately connected to the objects they fashion. The pre-literate society is not text-based; it is an aural culture, in which collective meaning is made via rites and rituals that are transformative, but without fixed or known outcomes. McLuhan believed that the advent of the printing press signified the beginning of the literate society. Here, means and ends become separated, technologies are subservient tools that fashion fixed outcomes; the means become subservient to the ends. This is a text-based society, dominated by visual media, such as books and painting. In the post-literate age, electronics have made communication immediate and pervasive; the world has once again become 'a global village'. Here, means and ends become blurred; technology is no longer subservient, but can instead be used to drive process and point toward new discoveries. McLuhan's famous phrase, "the medium is the message", reflects this blurring of means and ends. McLuhan believed that the post-literate world was akin to the pre-literate society in being an aurally dominated culture, in which frameworks that resembled rites and rituals intertwined with inseparable technologies, and that these rites and rituals were once again the dominant form of meaning-making in society. The performance of *The Beast* is rooted in the notion of the types of performances – intertwined with technologies – that adhere to the post-literate society.

So this performance work resides in the cybernetic ontology of emergence and becoming and it also inhabits McLuhan's framework of the post-literate society; this performance has no score or text, and no fixed outcome. The performers and audience enter the ritualised space of the theatre and a system or set of parameters is created in which narrative and meanings may emerge through transformational processes. There is no fixed outcome, only the desire that transformation will occur. Technology is utilised in the performance as an equal partner, driving process, and pointing toward new outcomes.

Finally, in considering the use of technology within this work and in the desire for the work to stage ontological theatre for the audience, it was felt that it was important to explicitly demonstrate how the work was being made within the performance in real time, to 'show the scaffold', so to speak, as the performance unfolds. This was done in several ways: the initial feedback tone, its recording and playing back into the space, demonstrates at the outset how the audio technology operates and the system that is at play within the performance. This is reflected in the actors' improvisations, which begin with the shaping of amorphous space and slowly develop over time into interactions, speech, and narrative scenes; the performance organically grows over time with no forced precepts. The audience is constantly reminded of the technological processes at play within the performance, as looped snippets of speech and sound from previous moments in the narrative are brought back into the space and interact with current themes. This explicit type of 'revealing' of process included within the performance chimes with Martin Heidegger's views on technology and its role in the world. Heidegger believed that technology is inseparable from us; it is intertwined with our being. Furthermore, technology is a malevolent force that conceals our true being. We cannot escape the all-consuming power of technology. However, Heidegger believed that it was possible to glimpse true being, on occasions, if technology could be used in a more radical and subversive way, one that made an attempt to reveal technology's true being and thus reveal our own.

Chapter 9

Conclusion

9. Conclusion

Spiegel: "And what takes the place of Philosophy now?"
Heidegger: "Cybernetics" (Martin Heidegger, 1981).

Throughout this thesis conclusions have been drawn, primarily in chapter 7, The Cybernetic Musical Framework. Seven indicators of cybernetic music were defined, which enabled practical investigation in the formulation of new, original cybernetic works. The following conclusion is a summary of the research and the main arguments put forward in this thesis. In addition, future areas of work are considered and the wider implications of cybernetic music on modern composition.

9.1. Summary

This thesis traced the development of a movement of music that draws direct influence from cybernetics. It encompasses composers who have directly utilised cybernetic theories in compositional practice and cyberneticists who have been involved in work with audio devices and music. The thesis began in Chapter 3 by examining cybernetic music in context, outlining a brief history of algorithmic composition and process music with electronics, and its relationship to cybernetic music.

In Chapter 4, a number of philosophical positions that related to cybernetics in music, in particular, writings concerning technology and praxis by philosophers such as Marshall McLuhan, Martin Heidegger, and Richard Coyne were examined. Coyne's work in particular, specifically his book *Designing Information Technology in the Postmodern Age: From Method to Metaphor* (1995) was critical in the formulation of the approach of this study. Coyne posits a pragmatic (as opposed to positivist or theoretical) approach toward computers in praxis, and asserts that ontology (and metaphor) is more useful in designing information technologies than epistemologies. Thus an emphasis on ontology was prevalent in this thesis both in the hermeneutical study of texts and in the investigation into the praxis of cybernetic music. In addition the phenomena of feedback was examined in detail. This examination was vital to understanding how systems interact and adapt to environments and therefore important to understanding the work of cybernetic composers and the formulation of the authors own practical work.

The musicological investigation proceeded in Chapter 5, with an examination of the founder of cybernetics, Norbert Wiener, and his work with the development of an assistive audio technology, the Hearing Glove. The work of Louis and Bebe Barron (Section 5.2), the founding pioneers of cybernetic music, was examined in the context of their work with John Cage and in the composition of the cybernetically composed music to the seminal science-fiction film *Forbidden Planet* (1956). Alvin Lucier's work (Section 5.3) with feedback and brainwaves was assessed in a cybernetic context, linking his philosophical pragmatism with his technological, compositional practice. The composer Herbert Brün's (section 5.4) close links with cybernetics and in particular his friendship with the eminent cybernetician, Heinz von Foerster, was explored as a direct influence on this work in computer-based composition. Roland Kayn's (section 5.5) relevance to electronic composition was also evaluated. His disagreements with the Darmstadt school and his prolific output of cybernetic music exemplify the juxtaposition of traditional electroacoustic music and cybernetic music, and point toward some of the unique qualities of this type of compositional practice. All of the aforementioned composers had close ties with the very earliest and most prestigious electronic music studios in Europe and America. They exemplify a different approach to electronic composition that existed between the end of the Second World War and the mid-to-late 1960s.

The composers examined subsequently in Chapter 6 reflected the sociological turn that cybernetics took in the late 1960s and the greater influence it exerted on artistic and popular culture as a result. The work of these composers reflects not only the possibilities that advancements in technology presented in this era, but also the extended philosophical discourse taking place within cybernetics at this time. Cyberneticist Gordon Pask's (section 6.1) work on his musicolour machine is examined and defined as one of the first 'learning machines' to be employed in creative music-making. The music producer and composer Brian Eno's (section 6.2) lifelong association with cybernetics and its influence on his musical output were also evaluated. Reflecting the influence of cyberneticist and friend Stafford Beer and his art school tutor and cybernetic artist, Roy Ascott, Eno's influence on popular music and his association with English minimalism make him perhaps the best-known advocate of cybernetic composition. Finally, the work of Agostino Di Scipio (section 6.3) and his cybernetic compositional ethos are examined in relation to the cybernetic compositions of Iannis Xenakis and Herbert Brün, bringing the historical musicological study up to the present day. Compositional structure, technological design, cybernetic influence, philosophical underpinnings, and relationships to cybernetic ontology were considered in the examination of each composer's works in order to assess commonalities in each aspect and to create an overriding compositional framework that defines practice in the area of cybernetic music.

The preceding literature review chapters (3, 4, 5 & 6) culminated in the cybernetic compositional framework in chapter 7, which postulates seven precepts necessary for engaging meaningfully in cybernetic composition. These precepts were presented as follows:

1) Ephemeral performance works
2) The non-necessity of notation in the post-literate society
3) The decentring of the composer
4) The inclusion of the environment in composition
5) A systemic human/machine/environment design ethos, which necessitates the composing of interactions rather than interactive composing
6) Compositional design based on feedback or recursive coupling
7) Ontological theatre – Heideggerian revealing

Chapter 7 formulates the theoretical, aesthetic and methodological basis of the practical work undertaken by the author in the subsequent chapter.

Chapter 8 of the thesis is an evaluation of three of the author's original cybernetic compositions. Each of these compositions adheres to the compositional framework and reflects the interrogation of different aspects of cybernetic music undertaken in the litature review.

First performed at ICMC 2016 in Utrecht, Holland, the first original composition analysed in chapter 8 was *Oscilloscope* (section 8.1), an interactive sound installation that utilises changes in light in an environmental space to trigger the tempos and ordering of a cybernetic musical system. The composition was based on Brian Eno's generative music systems and Agostino Di Scipio's sonic ecosystemic design. The camera and generative music system utilised in the design are also linked to an interactive generative computer animation created by Adam Collis, which reacts to the same changes in light intensity in the environment. Although all the original compositions adhere to every precept of the cybernetic compositional framework, *Oscilloscope* in particular was concerned with designing a composition based on feedback or recursive coupling and as such drew on ideas discussed in chapter 6 of this thesis.

Section 8.2 examines the cybernetician Stafford Beer's 'Viable System model' as a basis for real time composition. The methodology described here formed the basis of the subsequent compositions discussed in sections 8.3 (*Sin-Plexus)* and 8.4 *(The Beast*)

The second original composition examined in chapter 8 was *Sin-Plexus* (section 8.3), a live electroacoustic performance work with an accompanying computer animation, first shown at the International Computer Music Conference (ICMC) 2013, in Perth, Australia. The work utilises audio feedback as a basis for an emergent musical composition and has a complimentary interactive computer animation that responds to changes in the amplitude of the music. The work's technological design is based on Stafford Beer's VSM, as outlined in section 8.2. While this work extended ideas exploded in Brian Eno's work discussed in chapter 6.2, it also owes much aesthetically to the work of Louis and Bebe Barron, and the compositional ethos of Roland Kayn, both of which were examined in chapter 5 of this thesis.

The third original piece to be examined in section 8.4 was part of an improvised theatre work; *The Beast*, which incorporates long-form improvisational theatre accompanied by real-time cybernetic music that is generated from the sound of the actors' movements and speech. The music is fed back into the theatre space and acts as a springboard for scene-setting and further improvised narratives. *The Beast* was first performed publically at the Theatre and Performance Research Association conference at the University of Worcester, in September 2015. This performance work is in essence an extension of the compositional work undertaken in *Sin-Plexus,* with essentially the same feedback process being employed in the compositional design. However the work of Gordon Pask, discussed in chapter 6.1, in particular his *Musicolour* interactive learning machine, also had a major influence on the design of the interactions between the performers and technology within the work.

The 3 original compositions in chapter 8 drew influence from the previous musical applications and implementations of cybernetics in music and interrogated the theoretical, aesthetic, semiotic, and musicological ideas of cybernetic compositional practice through practical investigation. These original works also exemplify a practical application of the cybernetic compositional framework outlined in chapter 7, which enabled the exploration of the interrelationships of theory, practice, influence, and effect in a meaningful context.

9.2 Future work

The cybernetic music framework, outlined in chapter 7, provides fertile ground for future research in the area of cybernetic music, both as a spur for analytical study of electronic music and as a basis for future musical compositions.

Using the guiding principles of the cybernetic music framework, the author's own original compositions can be developed further, particularly in being more responsive to the environment and in recognition of its own internal states. In the composition of *Sin-Plexus*, some DSP automation was achieved via Max/MSP MIDI implementation but this aspect was underdeveloped in the final implementation due to processing constraints. However, this may be solved in future iterations via the use of two computers, one to process the audio functions and one to process the MIDI control functions. Further research in this area is underway.

A pertinent area of inquiry for future consideration by the author is in the realm of virtual and augmented realities. The development of these technologies is closely aligned to A.I. research (Coyne, 1995) and as such they have tended toward a Cartesian design ethos. The author believes that the application of cybernetics to this field of research will yield many interesting research questions relating to music, particularly when considering aspects such as immersion, interaction, intelligence and what constitutes a world, environment or reality. Sound and Music have a vital role to play in interrogating these questions and the cybernetic compositional framework offers a strong ontological position from which to enter this inquiry.

9.3 The Further Implications of Cybernetic Music

In order to define cybernetic music as a subset of electroacoustic music, we may return to the argument postulated in Chapter 4, concerning the role of the reductive and the generative paradigms in composition that utilises technology. In the reductive paradigm, electronic technology is a subservient tool that may assist in the compositional process and produce fixed and known outcomes. Here, the technology of notation is employed as the representational system utilised by the computer and the composer in order to accomplish the composition. This model is conceptually aligned to research in artificial intelligence, which utilises symbolic logic and representational systems as a means for a computer to understand external environments (Hofstadter, 2007). In the generative paradigm, the computer is used as an equal partner in the compositional process. The composition may be thought of as a 'seed' that grows into a musical structure. Here, outcomes are not fixed but adhere to a class of goals, which are defined by a heuristic conception imposed by the composer. Musical notation is no longer necessary as the composition is achieved not via representational means but by the design of interaction of components within a system. The composer Brian Eno sums up this compositional approach in the following terms: "instead of giving a set of detailed instructions about how to make something, what you do instead is give a set of conditions by which something will come into existence" (Eno in Toop, 2004). Design of a generative system is not predicated on an epistemology of music but on an ontology of biological systems. Needless to say, this model is aligned to cybernetics, which encapsulates a performative worldview in which an entity may only *know* its environment by interacting with it.

This thesis has examined this cybernetic standpoint and its influence on electronic music. Brian Eno notes that the cybernetic approach to composition is really one that is concerned with design and that this interest reflects a wider change in design ethos that has begun to permeate modern thinking. He observes that this reflects the: "change from an engineering paradigm, which is to say a design paradigm, to a biological paradigm, which is an evolutionary one. In lots of areas now, people say, how do you create the conditions at the bottom to allow the growth of the things you want to happen" (Eno in Toop, 2004). We may see this paradigm shift in solutions to many modern design problems that deal with complex systems, from river management to political and economic theories. So, in turn, we may also view cybernetic music's preoccupation with biological design as part of a larger paradigm shift that deals with how one might proceed in terms of interacting with and managing complex systems. This fact also highlights that cybernetic composers view the act of music composition as a complex system, which may only be understood through a biological design paradigm.

Thus we see a vastly different view of composition to traditional approaches. To further highlight this difference, we may consider music composition in the romantic tradition, where a lone composer hierarchically disseminates a platonically 'perfect' form for orchestras to play impeccably as the composer intended. Emotional meaning is imbued by the composer to be directly disseminated by an audience with no loss of transmission between the intentions of the composer and the interpretation of the audience. While many modern forms of composition seek to usurp this hierarchy (one may think of graphic scores or aleatoric processes), the mode of romanticism, which exalts the lone composer and the hierarchical dissemination of genius, was a prevalent concept in modernism and continues to pervade much current thinking. Cybernetic music obviously offers a different, non-hierarchical perspective, one that is particularly attuned to certain approaches to working with technology. Andrew Pickering notes that cybernetics offers a "constructive alternative to modernity. It humanises attractive possibilities for *acting differently*", in other words, it offers an alternative idea of how to 'go forward' in a world of exceedingly complex systems.

So, for the composer, the question of whether one might utilise cybernetic approaches in music making is not only about how one views the compositional process, but also one of how we might view the world, either as a rational and ultimately knowable place, or one that is exceedingly complex and ultimately unknowable. However, it is worth considering that while these two worldviews seem diametrically opposed, most modern composition with technology falls somewhere on a spectrum between these two polar opposites. One might imagine that were the framework espoused in this thesis more widely known, composers might have a yardstick by which to measure the 'cyberneticness' of their electronic compositions. This is somewhat to miss the point, however, as this thesis is intended to signpost a direction rather than impose rules. Nonetheless, It should also be noted that for many composers, the romantic and modernist traditions represent established and well-understood norms, while cybernetic music, by comparison, is obscure at best and for many represents unexplored territory. However, it is not the assertion of this thesis that cybernetic music should 'do away' with modernity altogether, but that it should be recognised as a legitimate strategy that might be adopted in music making. In speaking of how far the challenge to modernity that cybernetics represents should go, Andrew Pickering attests that while modernity is undoubtedly productive under certain circumstances (he cites power stations and modern physics as positive examples), its enframing nature is, however, very destructive: "what I have learned form Heidegger and cybernetics is to see it [the assumption of modernity's triumph] as a sad one. It closes us off from what the world has to offer; in the mode of enframing, the unexpected appears as a negative sign in front of it, as a nuisance to be got around. The stance of revealing, in contrast, is open to the world and expects novelty, for better or worse, and is ready for the former" (Pickering, 2011).

In terms of this thesis, the Heideggerian revealing that Pickering speaks of is the truly radical conception that cybernetic approaches offer us. So we may, once again, consider for a moment these revealing properties and why this is important to cybernetic composition. For Heidegger, the all-consuming enframing power of technology was destructive, as it concealed true being (and we should bear in mind here that Heidegger considered such things as writing and musical notation as technology, as well as computers). While he considered technology's enframing power to be inescapable, he did feel that resistance was possible in participation with technology in more radical ways and would thus reveal, if only fleetingly, the true nature of being. Heidegger's conception of how this mechanism of resistance might operate was the idea that the 'earth' was still present in technologies, that no matter how abstract and technologically sophisticated a thing is, it is still made of elements that can never be truly separated from their true being and that by revealing the 'things in themselves', we may come to a better understanding of true being. Richard Coyne gives an example of how a Heideggerian revealing might be beneficial. In examining the philosophy of Hubert Dreyfus and Thomas Kuhn, Coyne concludes:

> "Dreyfus demystifies Heidegger's concept of the earth within things by relating it to Kuhn's characterisation of anomalies in normal science. Heidegger's impenetrable earth is analogous to an anomaly that forces a revolution in science. As long as there are such anomalies and we are aware of them as such, there is the possibility of a breakdown in the current paradigm and the development of a new one. In the new paradigm, the anomaly becomes the focus of the new truth" (Coyne, 1995).

To evoke a speculative cybernetic music analogy, through the practice of cybernetic music it might conceivably be revealed that composers are not the sole arbiters of works of music. Environmental and technological factors also play an equal role in the construction of the work of music, and therefore, this aspect could plausibly be accepted as a new paradigm in composition.

Finally, perhaps the most radical conclusion to be drawn from this study is that cybernetic music (in some guise or another) is becoming the norm in terms of compositional mode, particularly in terms of electronic music. This thesis has returned many times to Marshal McLuhan's theory of the post-literate society (McLuhan, 1964) and has seen many parallels with these ideas and the form that cybernetic music presents. In illustrating McLuhan's ideas of the post-literate society in action, the postmodernist novelist Will Self has asserted that the novel is already dead as an art form because the technology that permitted its creation, the codex, is in rapid decline, superseded by interactive electronic media (Self, 2014). We might certainly draw parallels here with the demise of the Vinyl LP and its sister format the CD, leading to the demise of the album as the dominant art form in popular music (Helmore, 2013), and we must recognise that this undoubtedly also has major implications for the consumption of classical, avant-garde, and experimental music. If the recorded work no longer denotes the definitive performance of a piece of music, what does this imply for fixed media in general as a format for music? Certainly, questions of ephemerality and electronic media become more prevalent in this conception of a post-literate world and here we can see an alignment with cybernetic music. We may also see the negation of text-based forms, such as notation, as being a trope of the post-literate society, which in turn points toward cybernetic music (or something similar to it) as being the mode of meta-modern composition. These indicators do not predetermine the complete death of notation, popular music, or books, for that matter. As Self points out, it is the purview of the academy to preserve these art forms (Self, 2014). However, if we accept McLuhan's theory, these text-based and fixed-media forms are about to be superseded by some other mode. Cybernetic music points us to a way that we might 'go on' in this scenario. Certainly, a mode of revealing, rather than one of enframing, presents a more positive conception of the world and a viable way to proceed with electronic composition.

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Figures

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